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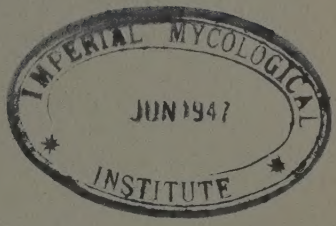

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VOLUME XLVI, № 2

TABLE DES MATIÈRES

Pages

MATHÉMATIQUES

M. M. Weinberg. On the Existence of an Eigenfunktion for a Class of Non-Linear Integral Equations 47
I. Shtokalo. Méthode asymptotique pour la solution de certaines classes d'équations différentielles linéaires à coefficients variables 51

ASTRONOMIE

A. B. Severny. On the Stability of Rotating Gaseous Spheres 53

PHYSIQUE DU GLOBE

W. B. Stockmann. An Attempt of a Qualitative Analysis of Temperature Conditions in the Region of Kurosio 56

CHIMIE PHYSIQUE

A. L. Rotinjan. On the Kinetics of Oxidation-Reduction Potentials 60
E. Shilov. Catalytic Inflammation of Chlorine-Ethylene Mixtures 64

CHIMIE BIOLOGIQUE

N. Diachkov aud **A. Kursanov.** The Carbohydrate Composition of Lichens of the Kola Peninsula Considered in Connexion with the Problem of Glucose Production in Northern Localities 65

GÉOLOGIE

S. V. Maximova. A Contribution to the Faunistic Characteristics of the Artinskian Stage s. str 69

A. A. Polkanov, Member of the Academy. On a New Deposit of Nephelite Rocks in the North-Western Part of the Kola Peninsula 72

HISTOLOGIE

A. A. Braun. The Connective Tissue Layers of Dermal Part of Skin in Vertebrates and Their Nomenclature 75

GÉNÉTIQUE

V. V. Sakharov, S. L. Frolova and **V. V. Mansurova.** Autotetraploidy in Different Varieties of Buckwheat *(Fagopyrum esculentum)* 79

PHYTOPATHOLOGIE

O. K. Elpidina. On Phytotoxins Occurring in Grain Responsible for «Septic Angina» 83

HELMINTHOLOGIE

E. A. Davtjan. Comparative Susceptibility of Molluscs to Invasion by Larvae of Nematodes, Causative Agents of Pulmonary Helminthoses in Sheep and Goat 86

Édition de l'Académie des Sciences de l'URSS
Moscou 1945

Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1945. Volume XLVI, № 2

MATHEMATICS

ON THE EXISTENCE OF AN EIGENFUNKTION FOR A CLASS OF NON-LINEAR INTEGRAL EQUATIONS

By M. M. WEINBERG

(Communicated by S. L. Soboleff, Member of the Academy, 13. IV. 1944)

In the present paper the following theorem is proved.

Theorem. *The non-linear integral equation*

$$\lambda u(x) = \int_B K(x, y)\, g(u(y), y)\, dy \qquad (1)$$

where B is a closed domain of one or more dimensions situated in a finite part of the space, x and y are points of this domain, and $g(0, x) = 0$ for all $x \in B$, possesses at least one non-trivial solution

$$u(x) = \psi(x) \not\equiv 0$$

which corresponds to a positive value of the parameter λ, if the following conditions are satisfied:

I. The nucleus $K(x, y)$ has only admissible discontinuities (in the sense of the theory of linear integral equations, is bounded, symmetrical and positive).

II. The real function $g(u, x)$ is continuous for all $x \in B$ and all u belonging to some interval containing zero.

III. For all $x \in B$ and u belonging to a certain interval $|u| < c_1$ hold the inequalities

$$ug(u, x) \geqslant 0; \quad |g(u, x)| \geqslant |f(u)|$$

where $f(u)$ is a function increasing in the interval $(-c_1, +c_1)$.

Remark. If $ug(u, x) \leqslant 0$, then the theorem remains valid with the qualification that the continuous solution corresponds to a negative value of the parameter λ.

A similar theorem was established by Lichtenstein (1) and Golomb (2) under different assumptions as regards the nucleus $K(x, y)$.

The proof of our theorem proceeds as follows.

If the nucleus $K(x, y)$ possess a finite number of Eigenfunktions

$$\varphi_1(x), \varphi_2(x), \varphi_3(x), \ldots, \varphi_n(x)$$

which correspond to the Eigenwerte

$$\lambda_1, \lambda_2, \ldots, \lambda_n \qquad (\lambda_{i+1} \geqslant \lambda_i > 0)$$

(in the sense of the theory of linear integral equations), the equation (1) has a

solution

$$\psi_n(x) = \sum_{k=1}^{n} \frac{\eta_k^{(n)}}{\sqrt{\lambda_k}} \varphi_k(x) \tag{2}$$

and

$$\lambda^{(n)} \psi_n(x) = \sum_{k=1}^{n} \frac{\varphi_k(x)}{\lambda_k} \int_B \varphi_k(y)\, g(\psi_n(y), y)\, dy \tag{2'}$$

$$\lambda^{(n)} = \frac{1}{c^2} \int_B \psi_n(x)\, g(\psi_n(x), x)\, dx \tag{3}$$

where the point $(\eta_1^{(n)}, \eta_2^{(n)}, \ldots, \eta_n^{(n)})$ of the n-dimensional Euclidean space is the point at which the auxiliary function

$$H_n(\xi_1^{(n)}, \xi_2^{(n)}, \ldots, \xi_n^{(n)}) = \int_B dy \int_0^{\sum_{k=1}^{n} \frac{\xi_k^{(n)}}{\sqrt{\lambda_k}} \varphi_k(y)} g(v, y)\, dv$$

defined on the sphere

$$\sum_{k=1}^{n} \xi_k^{(n)2} = c^2 \leqslant \frac{c_1^2}{\sup |K(x, y)|} \tag{4}$$

attains its absolute extremum.

If the nucleus $K(x, y)$ possesses an infinite number of Eigenfunktions

$$\varphi_1(x), \varphi_2(x), \varphi_3(x), \ldots$$

which correspond to its Eigenwerte

$$\lambda_1, \lambda_2, \lambda_3, \ldots \quad (\lambda_{i+1} \geqslant \lambda_i > 0)$$

we can consider the sequence

$$\lambda u(x) = \int_B K_n(x, y)\, g(u(y), y)\, dy \qquad (n = 1, 2, 3, \ldots) \tag{1'}$$

where the nucleus

$$K_n(x, y) = \sum_{k=1}^{n} \frac{\varphi_k(x)\, \varphi_k(y)}{\lambda_k}$$

and for every such equation find a solution $\psi_n(x)$. We obtain a sequence of functions $\{\psi_n(x)\}$ and a sequence of numbers $\{\lambda^{(n)}\}$ defined by the relations (2), (2') and (3).

The proof of the theorem reduces to choosing from the sequence $\{\psi_n(x)\}$ a subsequence which converges to a continuous and non-vanishing solution of the equation (1).

In the first line we prove that

$$\left| \frac{1}{\operatorname{mes}(\sigma B)} \int_{(\sigma B)} \psi_n(x)\, dx \right| \leqslant c_1 \tag{5}$$

where σB is the intersection of the domain B with the sphere σ of radius r with the centre at any point $t \in B$.

In proving (5) we use the boundedness of the nucleus and the well-known theorem on the decomposition of the nucleus (3). Since t and r are arbitrary, from (5) follows that the set of functions $\{\psi_n(x)\}$ is uniformly bounded. Hence

we conclude that the set of continuous functions $\{g(\psi_n(x), x)\}$ is also bounded. Then we consider the bounded sequence of positive numbers

$$l_n = \int_B |\psi_n(x)|\,dx \qquad (n = 1, 2, 3, \ldots) \tag{6}$$

which either tends to zero, or has for its exact upper bound a number $\alpha > 0$.

Consider first the case, when $\alpha > 0$. In this case there exists such a subsequence $l_{n_1}, l_{n_2}, l_{n_3}, \ldots$, that

$$l_{n_k} = \int_B |\psi_{n_k}(x)|\,dx > \frac{\alpha}{2} \tag{7}$$

To these numbers corresponds, according to the condition $ug(u, x) > 0$, a bounded sequence of positive numbers

$$\lambda^{(n_k)} \geqslant \frac{1}{c^2} \int_B \psi_{n_k}(x)\, g(\psi_{n_k}(x), x)\, dx \tag{8}$$

(cf. (3) and (4)).

It is necessary to find for the numbers of the sequence (8) an estimation from below. To this end we apply the condition III of the theorem. From this condition we have in the first place

$$\lambda^{(n_k)} \geqslant \frac{1}{c^2} \int_B |\psi_{n_k}(x)|\,|f(\psi_{n_k}(x))|\,dx \tag{9}$$

Consider further the set $A \in B$ on which $|\psi_{n_k}(x)| > \frac{\alpha}{4 \operatorname{mes} B}$, and let us estimate mes A by using the inequality (7):

$$\frac{\alpha}{2} < \int_A |\psi_{n_k}(x)|\,dx + \int_{B-A} |\psi_{n_k}(x)|\,dx < c_1 \operatorname{mes} A + \frac{\alpha}{4 \operatorname{mes} A} (\operatorname{mes} B - \operatorname{mes} A)$$

Hence

$$\operatorname{mes} A > \frac{\alpha \operatorname{mes} B}{4c_1 \operatorname{mes} B - \alpha} > 0$$

Apply now the fact that $f(u)$ increases in $(-c_1, +c_1)$. From this follows that if $|u| > \frac{\alpha}{4 \operatorname{mes} B}$, then $|f(u)| > \beta(\alpha) > 0$.

In view of this we find from (9) that

$$\lambda^{(n_k)} > \frac{1}{c^2} \int_A |\psi_{n_k}(x)|\,|f(\psi_{n_k}(x))|\,dx > \frac{\alpha^2 \beta(\alpha)}{4c^2(4c_1 \operatorname{mes} B - \alpha)} > 0$$

Thus

$$0 < \alpha_1 < \lambda^{(n_k)} < \alpha_2$$

where α_1 and α_2 are given numbers.

Choosing now from the sequence $\{\lambda^{(n_k)}\}$ a convergent subsequence $\{\lambda^{(m_k)}\}$, we shall have

$$\lambda = \lim_{m_k \to \infty} \lambda^{(m_k)} \tag{10}$$

where $0 < \alpha_1 < \lambda < \alpha_2$.

Further, from the properties of the nucleus $K(x, y)$ in view of the uniform boundedness of $\{\psi_{m_k}(x)\}$ follows that the sequence

$$\omega_{m_k}(x) = \int_B K(x, y)\, g(\psi_{m_k}(y), y)\, dy \tag{11}$$

is compact in C.

Consequently, there exists a subsequence of numbers $\gamma_1, \gamma_2, \gamma_3, \ldots$, such that

$$\lim_{k\to\infty} \omega_{\gamma_k}(x) = \omega(x) \tag{12}$$

Applying now the equality (2) and the well-known decomposition theorem (3), we obtain that

$$\left(\lambda^{(\gamma_k)}\psi_{\gamma_k}(x) - \int_B K(x, y)\, g(\psi_{\gamma_k}(y), y)\, dy\right) \to 0$$

uniformly. Hence and from (10) and (12) we find, in passing to the limit, that

$$\psi(x) = \lim_{k\to\infty} \psi_{\gamma_k}(x) = \frac{1}{\lambda}\,\omega(x)$$

and

$$\lambda\,\psi(x) = \int_B K(x, y)\, g(\psi(y), y)\, dy$$

where $\lambda > 0$ and $\int_B |\psi(x)|\, dx > \frac{\alpha}{2}$.

Finally, if $\alpha = 0$, then every function

$$\psi(x) = \sum_{k=1}^{\infty} \frac{\xi_k}{\sqrt{\lambda_k}}\,\varphi_k(x)$$

where $\sum_{k=1}^{\infty} \xi_k^2 = c^2$, is a solution.

In conclusion we may point out that the method used in the present paper enables us to find easily a denumerable set of Eigenfunktions $u_1(x)$, $u_2(x)$, $u_3(x)$, ... such that $u_n(x) \to 0$ uniformly as $n \to \infty$.

Red Army Institute
of Hydrometeorology.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1945 Volume XLVI, № 2

MATHÉMATIQUES

MÉTHODE ASYMPTOTIQUE POUR LA SOLUTION DE CERTAINES CLASSES D'ÉQUATIONS DIFFÉRENTIELLES LINÉAIRES À COEFFICIENTS VARIABLES

Par I. SHTOKALO

(Présenté par S. L. Soboleff, de l'Académie, le 10. IV. 1944)

Soit donné un système d'équations différentielles

$$\frac{dx}{dt} = [A + \varepsilon f(t)]\, x \tag{1}$$

où A est une matrice d'ordre n à éléments constants, $f(t)$ une matrice dont les éléments sont des sommes finies de la forme $\sum_{\mu} C_{\mu} e^{i\mu t}$ que nous nommerons dans la suite fonctions de classe $\sum$, x un vecteur n-dimensionnel et ε un paramètre positif.

If est facile à voir qu'une solution formelle de l'équation (1) est donnée par l'expression

$$x = \left[U e^{iBt} + \sum_{n=1}^{\infty} \varepsilon^n y_n(t) \right] \xi \tag{2}$$

où U et B sont des matrices à éléments constants (la seconde est une matrice diagonale à éléments réels), $y_n(t)$ est une matrice de classe $\sum$ et ξ est la solution formelle de l'équation à coefficients constants

$$\frac{d\xi}{dt} = \left(\sum_{n=0}^{\infty} \varepsilon^n A_n \right) \xi \tag{3}$$

Ainsi en substituant formellement (2) dans (1) on réduit ce système à un système (3) à coefficients constants.

On peut montrer qu'indépendamment de la convergence des développements formels, on peut tirer du critère de Hurwitz de la stabilité des solutions des systèmes linéaires (3) un critère pour la stabilité des solutions des systèmes (1). A cet effet il convient d'introduire la solution «abrégée» du système (1):

$$x = \left[U e^{iBT} + \sum_{n=1}^{m} \varepsilon^n y_n(t) \right] \xi \tag{4}$$

considérée comme un certain changement de variable.

Nous avons montré que la fonction ξ qui entre dans l'expression (4) présente une solution du système

$$\frac{d\xi}{dt} = \Big[\sum_{n=0}^{m} \varepsilon^n A_n + \varepsilon^{m+1} S_m(t, \varepsilon)\Big]\xi$$

où $S_m(t, \varepsilon)$ est une fonction de classe $\sum$, régulière par rapport à ε au voisinage de $\varepsilon = 0$.

Ainsi par le changement de variable (4) on réduit le système (1) à un système tel que la différence entre ces coefficients et certains coefficients constants sont des infiniment petits d'ordre aussi élevé que l'on veut.

L'évaluation asymptotique de l'erreur s'obtient d'une manière élémentaire dans le cas où toutes les racines de l'équation caractéristique pour $\varepsilon = 0$ ont des parties réelles négatives.

Quant au cas général, il a fallu pour le considérer démontrer toute une série de lemmes qui établissent le lien entre des parties réelles des racines d'une équation algébrique et les déterminants de Hurwitz.

En partant de ces lemmes, on a pu étudier l'allure à l'infini pour les solutions des équations différentielles linéaires à coefficients proches à des constantes en fonction de la borne inférieure des déterminants de Hurwitz, qui se rapportent à l'équation caractéristique pour les systèmes correspondants à coefficients constants.

En s'appuyant sur les raisonnements indiqués, nous avons établi le théorème suivant:

Supposons que les séries

$$\sum_{q=0}^{\infty} \varepsilon^q D_{l,q} \qquad (l = 1, 2, \ldots, m_n)$$

présentent les développements formels des déterminants de Hurwitz pour les systèmes (3), *et que* D_{l,q_l} *sont les premiers coefficients non nuls dans ces développements.*

Si tous les D_{l,q_l} $(l = 1, 2, \ldots, m_n)$ *sont positifs, on peut indiquer un* $\varepsilon_0 > 0$ *tel que pour*

$$0 < \varepsilon \leqslant \varepsilon_0$$

la solution du système d'équations (1) *tend vers zéro de façon exponentielle quand* $t \to +\infty$.

Mais si l'un au moins des D_{l,q_l} $(l = 1, 2, \ldots, m_n)$ *est négatif, il existe un* $\varepsilon_0^* > 0$ *tel que pour tous les*

$$0 < \varepsilon \leqslant \varepsilon_0^*$$

le système (1) *possède une solution non bornée pour* $t \to +\infty$.

On voit que le seul cas où le critère établi n'est pas applicable, est celui où tous les coefficients de l'un des développements des déterminants de Hurwitz pour les systèmes (3) sont nuls.

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ASTRONOMY

ON THE STABILITY OF ROTATING GASEOUS SPHERES

By A. B. SEVERNY

(Communicated by B. G. Fessenkow, Member of the Academy, 19. IV. 1944)

The preceding discussions showed[1] that the gaseous Emden's spheres are found in neutral equilibrium with regard to the spherical harmonic vibration of the first order, and all these spheres are stable in the same vibrations of the higher order. It has been suggested that this asymmetric vibration may lead to the fission of slow rotating sphere. However, this is quite natural if the rotation sinks the store of stability. Therefore, the problem of the stability of rotating gaseous spheres is of the fundamental importance.

The value of the non-dimensional parameter

$$\varepsilon^2 = \frac{\omega^2}{2\pi G \rho_0} \tag{1}$$

is less for our Sun than about $2 \cdot 10^{-5}$. For the stars of the early spectral classes this parameter is greater, but hardly exceeds 0.01 in a certain case. The expansions of the physical variables in series involving the ascending powers of ε give us, as has been shown by Milne ([2]) and Chandrasekhar ([3]), a powerful method for an approximative examination of the structure of the slow rotating stars. This method of expansions seems to be effective in the discussed problem of stability too, provided that the surface of the star may in the first approximation be considered a sphere. However, this simplified problem also involves great analytical difficulties, and is solved in this paper for the homogeneous sphere only.

We proceed from the equations of small motions of gases in the system of coordinates rotating with constant angular velocity ω, i. e. from the equations of the dynamical theory of tides ([4]). If δr, $\delta\theta$, $\delta\varphi$ are the components of the displacement $\vec{s}$ in polar coordinates and

$$\chi = U' - \gamma \frac{p_0}{\rho_0} \sigma \tag{2}$$

these equations of small motions may be written as follows:

$$\left.\begin{aligned}
(4\omega^2 - k^2)\,\delta r &= \left(1 - \frac{4\omega^2}{k^2}\cos^2\theta\right)\frac{\partial\chi}{\partial r} + \frac{4\omega^2}{k^2}\frac{\sin\theta\cos\theta}{r}\frac{\partial\chi}{\partial\theta} + \frac{2\omega}{ik}\frac{1}{r}\frac{\partial\chi}{\partial\varphi} \\
(4\omega^2 - k^2)\,r\delta\theta &= \left(1 - \frac{4\omega^2}{k^2}\sin^2\theta\right)\frac{1}{r}\frac{\partial\chi}{\partial\theta} + \frac{4\omega^2}{k^2}\sin\theta\cos\theta\frac{\partial\chi}{\partial r} + \frac{2\omega}{ik}\frac{\cos\theta}{\sin\theta}\frac{1}{r}\frac{\partial\chi}{\partial\varphi} \\
(4\omega^2 - k^2)\,r\sin\theta\,\delta\varphi &= \frac{1}{r\sin\theta}\frac{\partial\chi}{\partial\varphi} - \frac{2\omega}{ik}\left(\sin\theta\frac{\partial\chi}{\partial r} + \frac{\cos\theta}{r}\frac{\partial\chi}{\partial\theta}\right)
\end{aligned}\right\} \tag{3}$$

introducing the common time-factor e^{ikt} in the expressions of all the perturbations. Here U' is the perturbation of the gravitational potential; σ is the

condensation, and $\gamma p_0/\rho_0$ is the coefficient characterizing the compressibility of gases.

From these equations and the equation of continuity the following condition may be derived:

$$\nabla^2\chi - \frac{4\omega^2}{k^2} L(\chi) \equiv \nabla^2\chi - \frac{4\omega^2}{k^2}\left\{\cos^2\theta\,\frac{\partial^2}{\partial r^2} + \frac{\sin^2\theta}{r}\,\frac{\partial}{\partial r} + \right.$$
$$\left. + \frac{\sin 2\theta}{r^2}\,\frac{\partial}{\partial\theta} - \frac{\sin 2\theta}{r}\,\frac{\partial^2}{\partial r\,\partial\theta} + \frac{\sin^2\theta}{r^2}\,\frac{\partial^2}{\partial\varphi^2}\right\}\chi = (k^2 - 4\omega^2)\sigma \qquad (4)$$

for the homogeneous mass. At any point inside the mass the Poisson's equation gives

$$\nabla^2\left(\chi + \gamma\frac{p_0}{\rho_0}\sigma\right) = -4\pi G\rho_0\sigma \qquad (5)$$

At the surface of the rotating sphere $r = a$ must be

$$p' + (\vec{s},\ \operatorname{grad} p_0) = 0 \qquad (6)$$

where p' is the perturbation of pressure ($p' = \gamma p_0\sigma$). According to (3) and the condition of equilibrium

$$\frac{1}{\rho_0}\operatorname{grad} p_0 = \operatorname{grad}\Omega_0,\ \ \Omega_0 \equiv U_0 + \frac{\omega^2}{2} r^2\sin^2\theta \qquad (7)$$

the last equation will be

$$(k^2 - 4\omega^2)\frac{1}{g_a}\gamma\frac{p_0}{\rho_0}\sigma = \left(1 - \frac{4\omega^2}{k^2}\right)\frac{\partial\chi}{\partial r} + \left(\frac{4\omega^2}{k^2} + r\frac{\omega^2}{g_a}\right)\sin^2\theta\,\frac{\partial\chi}{\partial r} +$$
$$+ \left(\frac{4\omega^2}{k^2} + r\frac{\omega^2}{g_a}\right)\frac{\sin\theta\cos\theta}{r}\,\frac{\partial\chi}{\partial\theta} + \frac{2\omega}{ikr}\left(1 + r\frac{\omega^2}{g_a}\right)\frac{\partial\chi}{\partial\varphi};$$
$$g_a \equiv \left(\frac{\partial U_0}{\partial r}\right)_{r=a} \qquad (8)$$

where U_0 is the gravitational potential. (3), (4), (5) and (8) are the fundamental equations. We suppose the solutions of these equations to be in the form of expansions

$$\sigma = \sigma_0 + \varepsilon\sigma_1 + \varepsilon^2\sigma_2 + \ldots,\ \ \chi = \chi_0 + \varepsilon\chi_1 + \varepsilon^2\chi_2 + \ldots,$$
$$k^2 \equiv \lambda = \lambda_0 + \varepsilon\lambda_1 + \varepsilon^2\lambda_2 + \ldots \qquad (9)$$

In the «zero's» approximation we have the gaseous sphere at rest. In this case the solution is

$$\sigma_0 = \frac{1}{\sqrt{r}} J_{l+1/2}(\mu r)\, S_l(\theta, \varphi),\ \ \chi_0 = -\frac{\lambda_0}{\mu^2}\sigma_0 \qquad (10)$$

where S_l is the tesseral harmonic of the order 1, J is the Bessel's function and

$$\mu^2 = \frac{\lambda_0 + 4\pi G\rho_0}{\gamma p_0/\rho_0} \qquad (11)$$

The boundary conditions in this case will be

$$\text{for } r = a \quad \varphi\lambda_0\sigma_0 = \frac{\partial\chi_0}{\partial r},\ \ c \equiv \gamma\frac{p_0}{\rho_0}\Big/ g_a \qquad (12)$$

For the majority of gaseous spheres it may be taken $c = -1$ (according to the «virial» theorem), so that the condition (12) demands that the numbers $\mu a = z$ must be the roots of the equation

$$h_l(z) \equiv \frac{J_{l+3/2}(z)}{J_{l+1/2}(z)} = \frac{l - z^2}{z} \qquad (13)$$

The solution of this equation gives us the values of the least roots $z_0 = 0$; 0.92; 1.30 for $l = 0, 1, 2$, respectively; for any l we have $h_l(z_0) > 0$.

In the first approximation we get the system

$$\left.\begin{aligned} \nabla^2\gamma\frac{\rho_0}{\rho_0}\sigma_1 + 4\pi G\rho_0\sigma_1 + \lambda_0\sigma_1 + \lambda_1\sigma_0 = 0 \\ \nabla^2\chi_1 = \lambda_0\sigma_1 + \lambda_1\sigma_0 \end{aligned}\right\} \tag{14}$$

with the boundary conditions

$$\text{for } r = a \quad c(\lambda_0\sigma_1 + \lambda_1\sigma_0) - \frac{\partial\chi_1}{\partial r} = -\frac{i}{a}\sqrt{\frac{2\pi G\rho_0}{\lambda_0}}\frac{\partial\chi_0}{\partial\varphi} \tag{15}$$

The partial solution of the system (14) is

$$\sigma_1 = \left\{\frac{1}{\sqrt{r}}J_{l+1/2}(\mu r) - \frac{1}{2}\frac{\lambda_1}{\gamma p_0/\rho_0}\frac{1}{\mu}\sqrt{r}\,J_{l+3/2}(\mu r)\right\}S_l(\theta, \varphi) \tag{16}$$

$$\chi_1 = \left\{-\left(1+\frac{\lambda_0}{\lambda_0}\right)\frac{\lambda_0}{\mu^2}\frac{1}{\sqrt{r}}J_{l+1/2}(\mu r) + \frac{\lambda_0\lambda_1}{\gamma p_0/\rho_0}\frac{1}{\mu^3}\left[\mu\frac{1}{\sqrt{r}}J_{l+1/2}(\mu r) + \right.\right.$$

$$\left.\left. + \frac{\sqrt{r}}{2}J_{l+3/2}(\mu r)\right]\right\}S_l(\theta, \varphi) \tag{17}$$

Using these, the condition (15) gives

$$-\frac{1}{\lambda_1} = \frac{a}{s\sqrt{2\pi G\rho_0\lambda_0}}\frac{\rho_0}{\gamma p_0}\left\{\frac{\lambda_0}{\mu}\left[\frac{l+1}{2}h_l(z) - \left(\frac{l}{z}+\frac{z}{2}\right)\right] - \frac{c}{2}zh_l(z)\right\} \tag{18}$$

owing to the equations (12), (13); here $s = 0, 1, 2\ldots$ Near the state of neutral equilibrium there will be $\lambda_0 \approx 0$ for non-rotating gaseous sphere and $(c = -1)$

$$-\frac{1}{\lambda_1} \approx \frac{a}{s\sqrt{2\pi G\rho_0\lambda_0}}\frac{\rho_0}{\gamma p_0}\frac{z}{2}h_l(z), \quad \lambda_0 \to 0. \tag{19}$$

As we have $h_l(z_0) > 0$ for the slowest vibration of the order l, there always takes place the condition

$$\boxed{\lambda_1 < 0} \tag{20}$$

near the point of bifurcation. Consequently, in the first approximation the slow rotation of the homogeneous gaseous sphere sinks its store of stability near that point of bifurcation which corresponds to the spherical harmonic vibrations; in other words, the slow rotation makes the gaseous spheres to be more unstable than without rotation.

Sternberg State
Astronomical Institute.

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1945. Volume XLVI, № 2

GEOPHYSICS

AN ATTEMPT OF A QUALITATIVE ANALYSIS OF TEMPERATURE CONDITIONS IN THE REGION OF KUROSIO

By W. B. STOCKMANN

(Communicated by P. P. Shirshov, Member of the Academy, 13.III. 1944)

The current of Kurosio has been the subject of many papers published abroad, of which by far the major part is due to Japanese workers. Most of them are concerned with the hydrodynamical side of the question rather than with the thermal conditions. Thus, in a comprehensive work recently published by Koenuma only three pages are devoted to a cursory description of seasonal variations of temperature at some cross-sections of the current, which does not seem by any means to exhaust the possibilities which the observations referred to in his work offer for drawing a characteristics of the thermal regime of Kurosio.

So it is the author's object in the present paper to derive some conclusions relative to such a characteristics from a qualitative analysis of the brief information supplied by Koenuma on the seasonal variations of temperature at the Siono-Misaki cross-section.

In the adjoined table which I have borrowed from Koenuma ([1]) there are given the mean monthly temperatures for this cross-section, derived from observations carried on through a number of years, namely from 1923 to 1927.

Depth in m	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	20.10	19.66	19.62	20.49	22.33	24.13	26.45	28.12	28.11	25.69	23.40	21.69
25	19.88	19.46	19.33	20.29	21.86	23.52	25.39	27.17	27.57	25.49	23.21	21.62
50	19.60	19.40	19.24	20.15	21.33	22.78	24.19	25.80	26.48	25.37	23.19	21.65
100	19.41	19.05	18.91	19.52	20.08	20.98	21.86	22.23	23.05	23.33	22.30	21.26
200	18.43	18.03	17.62	17.86	18.30	18.52	18.45	18.70	19.40	19.48	18.79	19.05

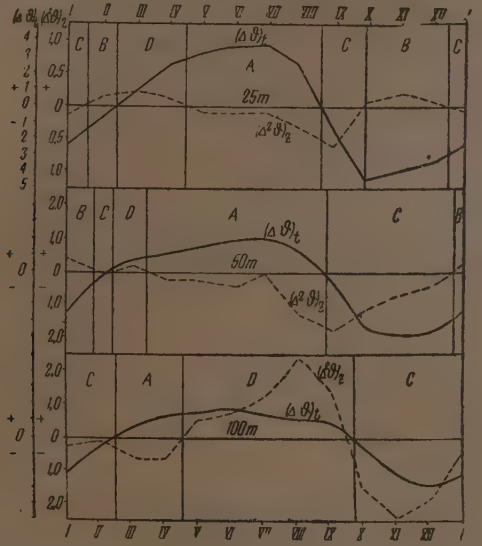
In order to subject the temperature conditions to a qualitative analysis I have plotted curves that bring out the yearly variations of the first temperature difference with respect to time $(\Delta\vartheta)_t$ for time intervals $\Delta t = 2$ months, and of the second temperature difference with respect to depth $(\Delta^2\vartheta)_z = \vartheta(z'', t) + \vartheta(z', t) - 2\vartheta(z, t)$ for levels lying 25 m, 50 m and 100 m below the sea surface.

The yearly run of these quantities is shown in the figure.

The values of $\Delta^2\vartheta/\Delta z^2$ can be obtained by dividing the plotted values of $(\Delta^2\vartheta)_z$ by $\Delta z^2 = 25^2$ m, $\Delta z^2 = 50^2$ m and $\Delta z^2 = 100^2$ m, respectively. It will be apparent that $(\Delta\vartheta)_t$ and $(\Delta^2\vartheta)_z$ have identical signs with $\Delta\vartheta/\Delta t$ and $\Delta^2\vartheta/\Delta z^2$.

Within the regions designated in figure as A and B the quantities $(\Delta\vartheta)_t$ and $(\Delta^2\vartheta)_z$ (or $\Delta\vartheta/\Delta t$ and $\Delta^2\vartheta/\Delta z^2$) have opposite signs.

Let us first consider those periods of time (of region A) when to a positive $\Delta\vartheta/\Delta t$ there corresponds a negative $\Delta^2\vartheta/\Delta z^2$. Clearly, the variation of tempe-



rature within these intervals is not accounted for by the processes of vertical heat conductance alone, for the coefficient of turbulent heat conductance k in

$$\left|\frac{\partial\vartheta}{\partial t}\right| = -k\left|\frac{\partial^2\vartheta}{\partial z^2}\right| \qquad (1)$$

is an essentially positive quantity, so that the equation cannot possibly be fulfilled. Adding, however, to the right-hand side of this equation the advective term

$$A_v = -u\frac{\partial\vartheta}{\partial x}$$

which in the case of Kurosio, a warm current, is essentially positive (the temperature falls off in the direction of the flow), we shall have a positive sign in the right-hand side of

$$\left|\frac{\partial\vartheta}{\partial t}\right| = -\left|k\frac{\partial^2\vartheta}{\partial z^2}\right| + |A_v| \qquad (2)$$

if $|A_v| > \left|k\frac{\partial^2\vartheta}{\partial z^2}\right|$, or the inflow of heat by advection predominates over the vertical transfer of heat by turbulence.

It may be inferred from this that in the intervals of time A the local variations of temperature at the Siono-Misaki cross-section are in the first place determined by the advection inflow of heat.

As is seen from the figure, the intervals A are very considerable in the surface layers (25 m and 50 m) where they extend mainly over the summer months. This may perhaps by taken to mean that the highest velocities of the current are not merely associated with its surface layers, but also predominate there during the warm season of the year (provided that the horizontal gradients of temperature are subject to little variation).

How nearly true is this conclusion cannot be decided at this juncture,

because we have no reliable data on the speed of Kurosio at the different times of the year, and there is divergence of opinion on that score.

However, the indirect evidences reported here seem to be trustworthy if one takes into account that during the summer — from May to October — the development of the Kurosio current may possibly be favoured by the light southerly winds which prevail in the south-west part of the Northern half of the Pacific, while in the winter months — from November to April — strong north-westerly winds blow in the opposite direction to the current, so that the surface layers of the latter may be expected to move at a reduced speed by that time.

Now we will turn to the parts of the graph designated as *C* and *D*. Note that the quantities $\Delta\vartheta/\Delta t$ and $\Delta^2\vartheta/\Delta z^2$ are negative within the time intervals *C* and positive within intervals *D*.

Making use again of the type (2) equation, in analysing the temperature regime qualitatively we get the following relation for the time intervals *C*

$$-\left|\frac{\partial\vartheta}{\partial t}\right| = -\left|k\frac{\partial^2\vartheta}{\partial z^2}\right| + |A_v| \qquad (2')$$

It follows from it that for the *C* periods the leading part in the variation of the temperature with time is played by the turbulent exchange, because necessarily

$$\left|k\frac{\partial^2\vartheta}{\partial z^2}\right| > |A_v|$$

As for *D* intervals, no definite conclusion can be reached by using the same qualitative method, because within these periods all the terms of equation (2) are positive and, generally speaking, there is an equal possibility for

$$k\frac{\partial^2\vartheta}{\partial z^2} > A_v \quad \text{or} \quad A_v > k\frac{\partial^2\vartheta}{\partial z^2}$$

Therefore the predominance of the turbulent exchange over the inflow of heat by advection in periods *D* can only be inferred from other considerations.

Let us finally analyse the temperature conditions at those intervals of time which are denoted by *B* in the figure.

In these periods, which occur only on the graphs for 25 and 50 m depths, the quantities $\Delta\vartheta/\Delta t$ and $\Delta^2\vartheta/\Delta z^2$ have unlike signs, just as in the first case (periods *A*). Yet in contrast with periods *A* the values of $\Delta^2\vartheta/\Delta z^2$ corresponding to the negative values of $\Delta\vartheta/\Delta t$ are here positive. Therefore the change of temperature with time within periods *B* will certainly fail to obey the equation of type (2), whose left-hand side will be found to be negative, while the two terms of the right-hand side will be both positive. If, however, allowance is made for the change of the mixing coefficient along the vertical, then instead of (2) we must write

$$\frac{\partial\vartheta}{\partial t} = \frac{\partial}{\partial z}\left(k\frac{\partial\vartheta}{\partial z}\right) + |A_v|$$

or

$$\frac{\partial\vartheta}{\partial t} = \frac{\partial k}{\partial z}\frac{\partial\vartheta}{\partial z} + k\frac{\partial^2\vartheta}{\partial z^2} + |A_v| \qquad (3)$$

The last two terms in the right-hand member of (3) are analogous to the right member of (2). And the first term in (3) allows for the influence of the variation of the mixing coefficient along the vertical. As in the *B* periods we have

$$\frac{\partial\vartheta}{\partial t} < 0, \quad \frac{\partial^2\vartheta}{\partial z^2} > 0 \quad \text{and, besides,} \quad \frac{\partial\vartheta}{\partial z} < 0$$

always (see table), therefore

$$-\left|\frac{\partial \vartheta}{\partial t}\right| = -\frac{\partial k}{\partial z}\left|\frac{\partial \vartheta}{\partial z}\right| + \left|k\frac{\partial^2 \vartheta}{\partial z^2}\right| + |A_v| \qquad (3')$$

Clearly (3') is not fulfilled unless

$$\frac{\partial k}{\partial z} > 0$$

and, moreover,

$$\left|\frac{\partial k}{\partial z}\right|\left|\frac{\partial \vartheta}{\partial z}\right| > \left|k\frac{\partial^2 \vartheta}{\partial z^2}\right| + |A_v|$$

Thus, we arrive at the important conclusion that the leading rôle in the local variations of temperature within B intervals is played by the variation of the mixing coefficient, and that the latter should increase with depth during these periods.

Curiously enough, the B periods which are particularly considerable at the 25 m depth, turn out to be associated with the autumn and winter season when the layers are the least stable along the vertical.

The result obtained agrees well with the general considérations as to the character of the vertical variation of the mixing coefficient as related to the vertical stability of the water masses.

In fact, the intensity of the turbulent exchange in summer should diminish down to a depth at which density suffers an abrupt drop of thermal origin and where the mixing coefficient is a minimum. Contrary to this, in autumn and winter, owing to the homogeneousness of the upper layers of the sea, the factors extinguishing the turbulence are absent, and it may be expected that by this time k is an increasing function of the depth.

A similar hypothesis as to the seasonal variations of the functional relation of k to z has formerly been put forward by Hidaka[2]. As we have seen, the results obtained corroborate the opinion of that worker.

Of course, the simple method employed here for a qualitative analysis of the temperature regime at the Siono-Misaki cross-section is in need of further improvement, and throws but a superficial light on the problems put forth here. These are to be solved in the future by arranging special observations.

The author has tried to make good use of the possibilities which the observations published by Koenuma (see table) afford for characterizing the thermal regime of Kurosio.

Laboratory of Oceanology.
Academy of Sciences of the USSR.

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PHYSICAL CHEMISTRY

ON THE KINETICS OF OXIDATION-REDUCTION POTENTIALS

By A. L. ROTINJAN

(Communicated by V. G. Chlopin, Member of the Academy, 31. V. 1944)

Investigating the kinetics of the establishment of equilibrium oxidation-reduction (O/R) potentials of the system $Pt/Tl_2(SO_4)_3$, Tl_2SO_4, H_2SO_4 on hydrogen-saturated electrodes, Rotinjan, Appenin and Tkachenko* obtained for some electrodes the potential—time curves given in Figs. 1 and 2.

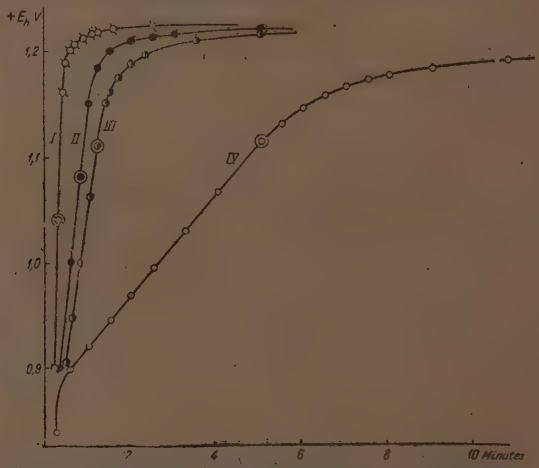

Fig. 1. Influence of dilution on the rate of equilibrium potentials. The $Tl_2(SO_4)_3$, Tl_2SO_4 and H_2SO_4 concentration of the initial solution is $6.250 \cdot 10^{-4}$ m/l, $3.125 \cdot 10^{-4}$ m/l and 0.174 m/l (the same for the entire series of experiments), respectively. *I*, initial solution; *II*, diluted twice; *III*, diluted four times; *IV*, diluted 20 times. Temperature 25°C. Electrode No. 4; dimensions: $25 \times 6 \times 0.05$ mm

The curves of the kinetics were explained by retarded establishment of gas equilibrium upon immersion of the electrode in the electrolyte. Retarded on an electrode saturated with hydrogen is the reaction $Tl^{\cdots} + 2H_{ads} \rightarrow Tl^{\cdot} + 2H^{\cdot}$, which removes excess H atoms from the surface of the platinum and reduces their surface concentration in accordance with the equilibrium potential of the O/R system.

* In the process of publication in the «Journal of General Chemistry» (USSR).

For a quantitative treatment of the kinetics of the given reaction it is necessary to find the connexion between the experimentally determined value of the change in potential with time and the rate of the surface reaction, and also to establish the relation between the surface concentration of the H atoms (C_H), and the electrode potential.

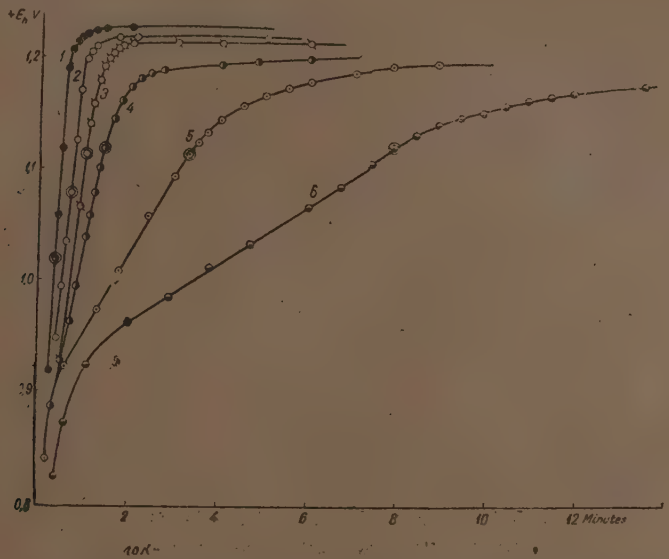

Fig. 2. Influence of the concentration of $Tl_2(SO_4)_3$ upon the rate of establishment of the equilibrium potentials. Concentration of Tl_2SO_4 was $3.125 \cdot 10^{-5}$ m/l and of H_2SO_4, 0.174 m/l. Concentration of $Tl_2(SO_4)_3$ was $6.250 \cdot 10^{-4}$ m/l for curve *1*; $3.125 \cdot 10^{-4}$ m/l for curve *2*; $2.188 \cdot 10^{-4}$ m/l for curve *3*; $1.250 \cdot 10^{-4}$ for curve *4*; $0.625 \cdot 10^{-4}$ m/l for curve *5* and $0.312 \cdot 10^{-4}$ m/l for curve *6*. Temperature 25° C. Electrode No. 5; dimensions: $25 \times 6 \times 0.05$ mm

As a first approximation we will assume that the capacity of the double layer (ε) is constant. Then:

$$-dC_H = \frac{\varepsilon}{nF}\,dE \quad \text{and} \quad -\frac{dC_H}{dt} = \frac{\varepsilon}{nF}\frac{dE}{dt}. \qquad (1)$$

i. e. the rate of the reaction is directly proportional to the rate of change in potential. Integrating (1), we get

$$-C_H = \frac{\varepsilon}{nF}E + \text{const} \qquad (2)$$

When $E = E_p$, $C_H = C_{H_p}$ (where the index «p» denotes equilibrium values), whence, taking into account that C_{H_p} is connected with E_p by the Nernst formula, we get

$$C_H = \frac{\varepsilon}{nF}(E_p - E) + \frac{C_H}{k'}\,10^{-E_p/0.059} \qquad (3)$$

Let us assume that $C_H \cdot k' \cdot 10^{-E_p/0.059} \ll \varepsilon\, nF\,(E_p - E)$. This will be true when $E_p - E \geq 0.001$ V and when the value of the capacity is most unfavoue-

able, if the order of k' is not greater than 10^{10}. Then we get:

$$C_H = \frac{\varepsilon}{nF}(E - E_p) \tag{4}$$

which gives a relation between C_H and the potential that is suitable for computations.

For the rate of the surface reaction let us write the expression

$$-\frac{dC_H}{dt} = kC_{Tl\cdots} C_H^2 \tag{5}$$

where $C_{Tl\cdots}$ is the concentration of $Tl\cdots$ at the surface.

In the initial stage of the experiment, $C_H \gg C_{Tl\cdots}$ and the rate of the reaction will depend only upon the concentration of $Tl\cdots$. For a heterogeneous reaction of the first order, when the rate of the reaction is commensurable with the rate of diffusion of the reacting substance to the surface, Frank-Kamenetzky found(1) a formula which when combined with(1) has the form:

$$\frac{dE}{dt} = \frac{k_1 nF}{\varepsilon\left(\frac{k_1\lambda}{D} + 1\right)} C \tag{6}$$

where D is the coefficient of diffusion of $Tl\cdots$, λ is the thickness of the Frunner layer, and k_1 is the rate constant of a monomolecular reaction.

In accordance with (6), at constant volume concentration of the reacting substance the rate of change in the potential should be constant, and the magnitude of the rate directly proportional to C. And indeed, linear segments are clearly visible on the curves in Figs. 1 and 2, and from Fig. 3 it is seen that the rate is a sufficiently satisfactory linear function of $C_{Tl_2(SO_4)_3}$ along these segments. The activity coefficient of the salt here was taken equal to unity.

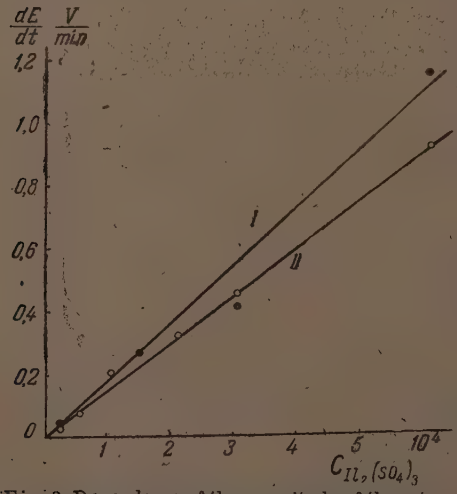

Fig. 3. Dependence of the magnitude of the rate along the linear segments of the potential—time curves upon the concentration of $Tl_2(SO_4)_3$

The different slope of the straight lines in Fig. 3 points to the catalytic influence of Pt upon the kinetics of the electrode reaction. Curve I corresponds to greater electrode activity, curve II to smaller. The linear relation between the rate of the reaction and the concentrations of $Tl_2(SO_4)_3$ follows from the premises of the diffusion theory of kinetics as well. However, the different slope of curves I and II from the point of view of this theory is incomprehensible, for if $C_{Tl\cdots}$ at the surface is equal to zero and the reaction rate is entirely determined by the rate of supply of $Tl\cdots$ to the surface, the catalysing influence of the electrode material should not make itself felt. Thus, it is more than likely that we are dealing here with the case considered by Frank-Kamenetzky.

The section of the curves up to the linear segment corresponds to a nonstationary state in which the concentration of the reacting substance at the surface of the electrode rapidly falls from its value in the volume to the value of $C_{Tl\cdots}$.

For the final stage of the experiment $C_{Tl}\ldots \gg C_H$, and the reaction rate will depend only upon C_H. Here, if $Tl^{\cdots}$ is reduced to $Tl^{\cdot}$ by two atoms of hydrogen simultaneously, the reaction will be of the second order with respect to H_{ads}. If, on the other hand, the reduction takes place consecutively, and, moreover, one of the stages proceeds much faster than the other, we get a reaction of the first order.

With the aid of (4) the equation for the rate of the first order reaction takes the form

$$k_1 t = \ln \frac{E_p - E_H}{E_p - E} \qquad (7)$$

and that for the rate of the second order reaction, the form:

$$k_2 t = \frac{nF}{s} \frac{1}{E_p - E_H} \left(\frac{E_p - E_H}{E_p - E} - 1 \right) \qquad (8)$$

where E_H is the potential corresponding to the moment when we begin to count time. In Figs. 1 and 2 the values of E_H have been denoted by circles.

In Fig. 4 are plotted the results of calculations with (7) and (8). The data of Fig. 1 are described by the equation of the second order (solid lines), and those of Fig. 2, by the equation of the first order (broken lines; curves *1* and *2* in Fig. 2 have not been plotted in Fig. 4).

The linear dependence between the time and the expression of the right side of eq. (7) and equation (8) holds satisfactorily on the whole. The independence of k_2 and k_1 of the Ox-form of the O/R system with a maximum deviation of up to 30 per cent from the mean value is arrived at by dividing their values by the volume concentration of $Tl_2(SO_4)_3$.

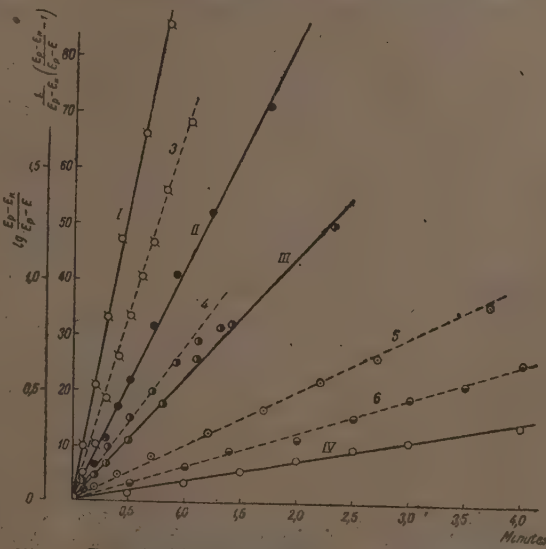

Fig. 4. Result of transformation of the curves in Figs. 1 and 2 with help of equations (7) and (8)

The observed order of the reaction depends on the catalytic activity of the electrode. High activity conditions a reaction of the second order, whereas less active electrodes may catalyse to a sufficient degree only one of the stages of the retarded reaction, and we get a reaction of the first order. An analogous picture of the dependence of the order of the reaction upon the state of the surface was observed, for example, by Wagner [2] in a study of the kinetics of the dissociation of hydrogen on Pd.

The intermediate state of the concentrations of $Tl^{\cdots}$ and H_{ads} occupies, apparently, quite a short period of time, since the curves of the kinetics throughout their course are described by equations (6), (7) and (8).

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PHYSICAL CHEMISTRY

CATALYTIC INFLAMMATION OF CHLORINE-ETHYLENE MIXTURES

By E. SHILOV

(Communicated by A. N. Nesmeyanov, Member of the Academy, 17.IV. 1944)

The inflammation temperature of chlorine-ethylene mixtures is dependent on the nature of the surface, on which the inflammation takes place. In the glass tubes the inflammation temperature of the mixtures containing 75—33 per cent chlorine and, resp., 25—67 per cent ethylene, lies between 225—260°, slightly depending on the percentage of the mixture *.

In quartz-glass tubes the temperature of inflammation is 20° lower than on glass and about 30° below that on soot formed by the flame.

Many metals and oxides have no action on the inflammation temperature (in glass tubes). These are: Fe, Sb, CuO, Cu_2O, MgO, CdO, SnO_2, MoO_3, Fe_2O_3.

Flashes on barium oxide were registered at 160° C.

Oxides of mercury, silver and lead have a strong catalytic action. On dry mercuric or mercurous oxide and on silver oxide chlorine-ethylene mixtures inflame at room temperature. On lead oxide the inflammation occurs usually at 100—120° C. but occasionally at 45° C. Pb_3O_4 and PbO_2 are markedly less active.

Lead oxide can cause an explosion at room temperature, if introduced as powder into a capacious vessel containing chlorine-ethylene mixture. Mixtures of chlorine with methane or hydrogen explode also if initiated by HgO or Hg_2O in large vessels. The action of lead oxide is apparently insufficient to cause an explosion of such mixtures, even in large vessels, at low temperatures.

Curiously enough, powdered antimony and reduced iron fail to ignite chlorine-ethylene mixtures, though these metals react energetically with chlorine in gaseous mixtures.

The initiating oxides undergo chemical changes, being converted into chlorides and other compounds. Hg_2O yields chloride and metallic mercury. PbO forms chloride (or oxychloride) and lead peroxide.

It might be argued that the initiating action of metallic oxides is due to the formation of chlorine oxide which is a result of the reaction of chlorine with many oxides, particularly, with mercuric oxide. But our experiments indicate that the inflammation temperature of chlorine-ethylene mixtures does not fall off below 135—155° C, and goes never down to room temperature. Moreover, it was stated that a moistening of the oxide inhibits the ignition, though the formation of chlorine oxide is known to be unaffected by the presence of moisture.

The catalytic ignition of mixtures of chlorine with hydrocarbons ought rather to be compared with certain remarkable oxidations observed by Michael and Murphy (2). They reported that the action of silver oxide on chlorine solution in CCl_4 leads to formation of phosgene. In the absence of chlorine CCl_4 is oxidi-

* Rust and Vaughan stated that the inflammation temperature of chlorine-ethylene mixtures rises, if small amounts of nitrogen or oxygen are present. The nitrogen-free mixtures inflamed in their experiments at 215° (apparently on glass) (1).

zed only at 250° C. Nor does chlorine oxide react with CCl_4 at room temperature. Therefore chlorine appears as catalyst in the reaction between CCl_4 and Ag_2O.

It may be assumed that chlorine molecules joining with metal-atom of the oxide make the oxygen atom of the oxide extremely active. In this state oxygen atom unites easily with hydrogen or carbon atom of organic molecules. In this way radicals appear which lead the chain reaction to inflammation.

Experimental. The gaseous mixtures were composed for the most part in the reaction tube by mixing the flowing chlorine and ethylene (or any other gas), the rate of flow being controlled by rheometers. The gases, of usual laboratory purity, were dried over calcium chloride. The reaction tubes, 6 —12 mm in diameter, were placed in a groove trenched in an aluminium core, 24.5 cm long, heated by a burner. A thermometer was placed inside the reaction tube immediately after the catalyst, placed powdered in the middle of the tube as a layer 2—3 cm long. A narrow longitudinal slit was provided to observe the tube during the experiment.

The inflammation of a gaseous mixture takes place generally on the surface of a catalyst, or at the end-piece of the tube in the absence of catalyst.

The flame propagates mostly noiseless, back to the point of mixing of gases, where it extinguishes. In a few moments a new flash starts, and the tube becomes gradually coated by charry deposit.

The detonations accompanied by a loud knock and destruction of the reaction tube were observed occasionally at the initiating by a catalyst, particularly in the presence of ether, or at ignition of mixtures of chlorine and methane.

Several experiments were made in 0.5—1 liter jars, connected with a manometer and protected from light. After evacuation the jars were filled by chlorine and ethylene in a proportion 2 : 1 by volume. It was stated in control experiments that during the filling of the vessel only 2 per cent chlorine and ethylene disappear, entering into reaction. Immediately after filling with gases some catalyst powder was introduced from a little ampoule, connected with the jar by a rubber tube. An explosion caused by a tiny amount of catalyst breaks the jar to pieces with a deafening knock.

Chemico-Technical Institute,
Ivanovo.

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1945. Volume XLVI, № 2

BIOCHEMISTRY

THE CARBOHYDRATE COMPOSITION OF LICHENS OF THE KOLA PENINSULA CONSIDERED IN CONNEXION WITH THE PROBLEM OF GLUCOSE PRODUCTION IN NORTHERN LOCALITIES

By N. DIACHKOV and A. KURSANOV

(Communicated by A. N. Bach, Member of the Academy, 9. VI. 1944)

The lichens have always attracted the attention of numerous investigators as an example of most remarkable biological symbiosis.

Being composed mainly of a fungus and a green (less frequently, a bluish-green) alga, the lichens display two types of metabolism: an autotrophic, inherent in algae, and a heterotrophic, distinctive of the fungal component. According to the ratio alga/fungus and the relative metabolism intensities of the two components, individual lichen species have been found (1) either to satisfy their requirement for organic substances by means of photosynthesis, as *Lobaria*, or to stand in need for supplementary sources of organic matter, as *Umbilicaria*.

Aside from their peculiar mode of life, the lichens are also remarkable for their rather singular chemical composition, and the carbohydrate composition in particular. Only a few of the carbohydrates they contain are in the form of simple reducing sugars. The same holds good for the cellulose which in this series is a product of the highest polymerization. The bulk of the carbohydrate complex is represented by a group of hydrolysed polysaccharides of the hexose type, part of which is soluble in hot water, while the other is not. The former, which is especially characteristic of the species *Cetraria*, was described as far back as by Bercelius (2) by the name of lichenin or lichen starch, whereas the second was termed lichen cellulose by the same author. It should be noted, however, that when subjected to fermentative hydrolysis, lichenin has been found by Karrer (3), Pringsheim (4) and some others to decompose into cellobiose rather than into maltose, which is a feature in common with cellulose.

The water insoluble part of the polysaccharides has been studied to much lesser extent. The only information due to Hesse (5) consists in that when subjected to hydrolysis with acid it is readily soluble and is almost quantitatively decomposed into glucose, containing galactose and mannose as admixtures only.

The group of soluble carbohydrates to which we give the name of lichenin is not homogeneous, but consists of several substances closely related to one another. Hesse distinguishes among them lichenin proper, *d*-lichenidin and lichenoin. Under the influence of diluted acids they all rather readily decompose into glucose. Salkowsky (6) has besides suggested to distinguish isolichenin which is soluble in cold water and gives a blue staining with iodine (7, 8). Recently the soluble polysaccharides have been subdivided into pustulin, lichenin and evernin, the first among which is not, while the two others are precipitated with tannin from water solutions.

Among the rest of substances typical of the lichens the so-called lichen acids should be pointed out, and the related neutral compounds which are substances

of the phenol type. The best studied of these is the lecanoric acid ($C_8H_{14}O_7$), synthesized by Fisher in 1913 (4). By far more scanty is the information available for the rest of lichen acids, though they are known to present a great variety, according to Hesse. The content of these substances in lichens usually makes up 2—3 per cent, but in individual species, as for example in *Roccella* and *Arthonia*, it may attain 23 per cent to the dry weight of the plant.

In addition to these substances the lichens usually contain a very small amount of ash, proteins (3—4 per cent), and fat (1—3 per cent). The chemical properties of the two last groups have been but little investigated.

In 1943—44 the present authors carried out a study of the carbohydrate composition of the lichens encountered in the Khibiny Tundra; the work was carried out in the laboratory of the Polar Botanical Gardens of the Academy of Sciences of the USSR. The results are summed up in the table below.

Carbohydrates Contained in Certain Lichen Species
(in per cent to dry weight of plant)*

Lichen	Carbohydrates of $C_6H_{10}O_5$ type				Total of carbohydrates $C_6H_{10}O_5$	Pentosanes
	Water soluble		Water insoluble			
	simple sugars	lichenin	hemicelluloses	celluloses		
Cetraria islandica	1.9	50.9	25.8	3.9	82.5	2.0
C. nivalis	1.5	18.8	59.7	3.9	83.9	4.3
Alectoria ochroleuca	1.2	45.6	34.6	3.7	85.1	2.0
Cladonia alpestris	0.3	2.4	73.8	7.3	83.8	1.1
C. mitis	0.4	1.6	71.6	6.6	80.2	1.3
C. deformis	0.3	4.1	68.5	10.8	83.7	1.2
Peltigera	0.4	4.9	35.2	8.3	48.8	—
Stereocaulon paschale	1.1	2.9	59.8	8.6	72.4	—

From the data contained in this table it may be seen that the total amount of the carbohydrates built up of hexoses in most of lichens makes from 80 to 85 per cent to their total mass. The quantity of pentosanes is a relatively small one; however, they are distinctly observable in all the lichen species investigated. Hesse's assertion (5) as to the absence of pentoses in lichens cannot be qualified otherwise than as a mistake. As mentioned above, the amount of simple sugars is very small in lichens. Neither do they contain much cellulose, though in *Cladonia* species it amounts to 6—10 per cent. The species of *Cetraria* and *Alectoria* are much lower in cellulose. Their main mass is composed by substances of the type of lichenin or hemicellulose; it is noteworthy that in certain lichens (*Cetraria islandica* and *Alectoria ochroleuca*) water soluble carbohydrates, *i. e.* lichenins, are prevalent, whereas in others hemicelluloses are prevailing. If we neglect cellulose as a product which presents difficulties in hydrolysing, and leave out of account pentosanes, then the rest of substances which are able to be converted into glucose under slight acid hydrolysis make up from 70 to 82 per cent. Out of the species listed in the table the two last only show lower figures.

The analyses of *Cladonia* species collected by the authors in 1942 along the Wychegda River (the Komi ASSR) have shown them to be as high in carbohydrates as the *Cladonia* growing at the Kola Peninsula.

Thus, when subjected to slight acid hydrolysis various lichen species may yield so high an amount of glucose, as to make them comparable with potato and sugar-beet.

At the same time the natural resources of lichens are immense throughout the northern part of this country, while they find scarcely any economic application save for reindeer feeding. The lichen growths form mostly immense car-

* L. J. Avrorina and G. M. Saychenko, analysts.

pets spreading over vast territories. In such regions their yield is likely to attain 5 tons of dry lichen per hectare. Suffice to note that, according to data by E. G. Chernov, the resources of lichen in a single region of the Murmansk province amount to 600 000 tons of dry matter.

All that has been said above induced the authors to raise the question as to the using up of lichens for the production of glucose. The method of production of glucose molasses and glucose from lichens is based upon the hydrolysis of the lichens with sulphuric acid, with a subsequent boiling of the hydrolysate neutralized with chalk and purified with activized coal to a thick syrup containing up to 65—70 per cent of dry matter. Such a syrup, or molasses, if left to stay is readily crystallized into lump glucose.

The presence in the raw material of lichen acids responsible for the bitter taste impairing the end-product makes it necessary to treat the lichens before hydrolysing with weak alkali solutions; the insoluble lichen acids are thus transformed into their soluble potassium or sodium salts [10].

Following our scheme, at the town Kirovsk were built in 1943—1944 two small factories capable to produce up to 80 kg of lichen molasses per day each. These plants are the first enterprise of this kind all over the world.

Experience has shown that not all lichen species are equally suitable for the purpose here discussed. In the first place, of inferior quality are lichens of the type of *Stereocaulon* and *Peltigera* (see table). Moreover, lichens belonging to the group of *Cladonia*, especially *Cladonia alpestris*, yield molasses of a pronouncedly bitter taste. As shown by special tests, this bitterness is due not to the lichen acids which can easily be eliminated by treating the material in the usual way with alkali, but rather appears during the process of hydrolysis. The nature of the substances responsible for the bitter taste, and the possible methods of their elimination are the subject of our actual studies. Unlike the lichen species referred to above, *Cetraria islandica*, *C. nivalis*, and *Alectoria ochroleuca* and *nigricans*, as well as the epiphytic *Usnea barbata* and *Bryopogen habeiliforme* yield a product of sufficient purity and sweetness. The output of glucose molasses, with a content of 65—70 per cent glucose, amounts to 100 per cent to the initial dry weight of the lichen.

The Polar Botanical Gardens.
Academy of Sciences of the USSR.
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GEOLOGY

A CONTRIBUTION TO THE FAUNISTIC CHARACTERISTICS OF THE ARTINSKIAN STAGE S. STR.

By S. V. MAXIMOVA

(Communicated by W. A. Obruchev, Member of the Academy, 12. V. 1944)

While working on the Yurezan River (between the Bolshaya Luka and the Idelbaevo village), and on the Ai River (between the Lakly village and the Mesyagutovo village), the author has collected some interesting material concerning the fauna of the Artinskian stage s. str., which permit of certain conclusions and correlations*. Before passing to the discussion of the material, it should be noted that as the lower boundary of the stage we adopt the bottom of the layers with *Pseudofusulina plicatissima* Raus. and *Ps. urdalensis* Raus., and as the upper boundary, perforated breccia-like limestones.

The section of the Artinskian stage on the Yurezan may be briefly represented as follows:

Series P_1a_1. In the lower part it contains a conglomerate, higher up a thin horizon of organogenous limestones; and still higher, clays intercalated with sandstones and rarely detrital limestones. The following forms have been found in the organogenous limestones: *Pseudofusulina urdalensis* Raus., *Ps. plicatissima* Raus.. *Ps. plicatissima* var. *irregularis* Raus.. *Ps. urdalensis* var. *abnormis* Raus., *Echinoconchus* cf. *sterlitamakensis* Step., *Productus* (*Avonia*) cf. *pseudoaculeatus* Krot., *Dictyoclostus* cf. *gruenewaldti* Krot., *Spirifer poststriatus* Nikit.. *Sp. rectangulus* Kut. In the stratum of detrital limestone, among clays, *Pseudofusulina plicatissima* Raus. and *Ps. urdalensis* Raus. have been found. Thickness, 60 m.

Series P_1a_2. Brownish-grey soft clays with lenses and beds of clayey limestones and sandstones. In the upper portion three layers of bituminous marl, each 6—7 m thick. In the lower half of the series the following ammonoids have been found: *Neopronorites permicus* (Tschern.), *N. skvorzovi* (Tschern.) var. *simplex* Max., *N.* cf. *mojsisovicsi* (Karp.), *Daraelites elegans* Tschern., *Popanoceras tschernovi* Max., *Kargalites* ex gr. *typicus* Ruzh., *Agathiceras uralicum* Karp., *Paragastrioceras* cf. *tschernovi* Ruzh., *Neoschumardites triceps* Ruzh. In the bituminous marls the following fusulinids have been discovered: *Pseudofusulina schellwieni* Viss. (abundant), *Ps.* ex gr. *schellwieni* Viss., *Ps.* cf. *juresanensis* Raus., *P.* cf. *lutugini* Schellw., *Ps. concessa* Viss. Thickness, 150 m. The fusulinid complex is characteristic of the Burtzev series of Rauser-Chernoussova.

Series P_1a_3. Bituminous marls with rare layers of clays. No fauna has been found. Thickness, 200—300 m.

Series P_1a_4. Different-grained sandstones, clays and marls. There occur beds of detrital limestones and peculiar conglomerate limestones. In the

* The identifications were made by S. V. Maximova (ammonoites), D. M. Rauser-Chernoussova (fusulinids), and D. L. Stepanov (brachiopods).

lower part of the series, in the bed of detrital limestone the following fusulinids and brachiopods have been found: *Pseudofusulina kutkanensis* Raus., *Ps. juresanensis* Raus., *Ps. schellwieni* Viss., *Staffella pseudosphaeroidea* Dut., *St. preobrajenskyi* Dut., *St. dagmarae* Dut., *Rhipidomella uralica* Tschern., *Chonetes sinuatus* Krot., *Dictyoclostus gruenewaldti* Krot., *D. uralensis* Lich.; *D. moelleri* Stuck., *Linoproductus cora* d'Orb., *Productus orientalis* Frcks., *P.* (*Thomasina*) *artiensis* Tschern., *P.* (*Echinoconchus*) *sterlitamakensis* Step., *P.* (*Waagenoconcha*) *humboldti* d'Orb., *P.* (*Avonia*) *pustulatus* Keys., *P.* (*Avonia*) *pseudoaculeatus* Krot., *P. stuckenbergianus* Krot., *Marginifera septentrionalis* Tschern., *Spirifer poststriatus* Nikit., *S. expansus* Tschern., *Spiriferella saranae* Vern., *Spiriferina cristata* Schloth., *Sp. pyramidata* Tschern. The fusulinid complex is characteristic of the Burtzev series of Rauser-Chernoussova. Thickness, 450 m.

Series P_1a_5. Different-grained arkose sandstones with clays and arenaceous clays. Here the following forms have been found: *Neopronorites permicus* (Tschern.), *Artinskia artiensis* (Grün.), *Medlicottia orbignyi* (Vern.), *Propinacoceras ajense* Max., *Waagenina krasnopolskyi* (Karp.), *Popanoceras hanieli* Smith, *Paragastrioceras auriculatum* Max. Thickness, 250 m.

Series P_1a_6. Interbedded thin layers of clays, marls and sandstones, with rare limestones. The following ammonites and fusulinids have been found: *Neopronorites permicus* (Tschern.), *Medlicottia or bignyi* (Vern.), *Paragastrioceras fedorovi* (Karp.). *Pseudofusulina callosa* Raus., *Ps. concessa* Viss., *Ps.* ex gr. *schellwieni* Viss., *Ps.* ex gr. *lutugini* Schellw. The fusulinids, as seen from the list, are poorly preserved, but the complex has the habit of the Burtzev series. Thickness, about 200 m.

Series P_1a_7. Sands, clays, calcareous sandstones and marls. In the upper portion of the series there are gypsum intercalations. No fauna is found. Vegetable remains occur. Thickness, 100 m. This series is overlain by perforated breccia-like limestones.

From an examination of the section, the following interesting conclusions may be made. 1) Throughout the whole of the Artinskian stage, beginning with series P_1a_2 and ending with series P_1a_6, the same complex of fusulinids is observed, which is characteristic of the Burtzev series, and in no place does *Pseudofusulina lutugini* Schellw. occur in abundance. In other words, here the complex of the Irgina horizon, as understood by Rauser-Chernoussova, is absent, and the fusulinids are, as it were, stabilized on those forms which in the carbonate sections characterize the strata lying below the zone of an abundant development of *Pseudofusulina lutugini*. 2) This Burtzev complex occurs not only below, but also above the layers containing such guide Artinskian species of ammonoids, as *Artinskia artiensis*, *Medlicottia orbignyi*, *Waagenina krasnopolskyi*, *Paragastrioceras fedorovi*, and *Neopronorites permicus*.

Such a distribution of fauna is observed not in our section only. In the Belokataisk region, according to the data of A. V. Khabakov, in the P_1 art_{II} and P_1art_{III} series, above the layers containing *Medlicottia orbignyi* and *Paragastrioceras fedorovi*, the fusulinids are also represented by forms characteristic of the Burtzev series: *Pseudofusulina juresanensis*, *Ps. kutkanensis*, *Ps. schellwieni*, very rare *Ps. lutugini*. Here, up to the topmost portion of the Artinskian stage, the complex of the Irgina horizon with abundant *Pseudofusulina lutugini* has not been discovered.

In the Orenburg-Aktiubinsk region, according to data of D. M. Rauser-Chernoussova, up to the topmost portion of the Artinskian stage, *Pseudofusulina schellwieni*, *Ps. juresanensis*, *Ps. kutkanensis* are present, *Ps. lutugini* being absent. As far as one may judge from a comparison of the data of Rauser-Chernoussova and of Ruzhencev, this complex of fusulinids occurs partly at one stratigraphical level, partly above the rich ammonoid faunas of the Aktiubinsk region, including all the species known from the vicinity of the Artinsk Works. Finally, after Keller, the fusulinids in the Artinskian stage of the left bank of the B. Syuran River are also ending with the Burtzev complex.

At this point it should be noted that the fusulinids of the Artinskian stage have been very little studied till now and are now being revised. A number of species have been already further subdivided, and the stratigraphical distribution of each form is being revised, which may, naturally, introduce some change into the characteristic and treatment of the previously identified faunas. However, with all possible changes, some conclusions may be made quite definitely. The fact is that in the vast majority of the sections of the Artinskian stage, both of the limestone and the terrigeneous ones, the fusulinids were identified by one and the same person (D. M. Rauser-Chernoussova), who had a similar understanding of the scope of a species; hence, whatever the accuracy of the determinations, it was of the same degree in all cases. If we compare (supposing them to be equally well investigated) the limestone sections (Ishimbay, Chussovskie Gorodki) with the terrigeneous sections cited above, we see that in the former the Burtzev series is overlain by the horizon with abundant *Pseudofusulina lutugini*, while in the latter, in all of the Artinskian deposits characterized by the guide species of ammonoids, the above-named horizon is invariably lacking.

Considering the fact that fusulinids have not been studied sufficiently, two alternative explanations may be offered: 1) If in the upper part of the Artinskian stage a separate complex of fusulinids be isolated, differing from those lying below, it will mean that the horizon with abundant *Ps. lutugini* is not a stratigraphical unit, but only a separate facies peculiar of the carbonate sections to which in the terrigeneous sections correspond strata characterized by different species. 2) If the fusulinids of the Artinskian stage are found to belong to one single complex, as it may be presumed with the present state of our knowledge, it will signify that to the horizon with abundant *Ps. lutugini* will correspond a part of the present Kungurian stage. This version of correlation is given in the paper of D. M. Rauser-Chernoussova (1904) in comparing her stratigraphical scheme with that of V. E. Ruzhencev for the Aktiubinsk-Orenburg region.

An evidence in favour of this view is presented also by the occurrence on the Ai River, near the Alegasovo village, of Artinskian ammonites (*Paragastrioceras fedorovi*, *Thalassoceras gemmellaroi*) above the perforated limestones.

However it may be, with either version two points remain unchanged, namely:

1) It cannot be admitted that the lower portion of the Artinskian stage is characterized by the presence of *Pseudofusulina lutugini*, and the upper, by ammonoids of the Artinsk Work. These fossils exist either simultaneously, or *Ps. lutugini* occur also above the Artinskian ammonoids.

2) The boundary between the Permian and the Carboniferous cannot be drawn along the bottom of strata with abundant *Ps. lutugini*. If it be only a separate facies, the question is quite clear; if these strata correspond to the Kungurian, it would be necessary to refer to the Carboniferous the deposits containing classical Artinskian ammonoids.

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GEOLOGY

ON A NEW DEPOSIT OF NEPHELITE ROCKS IN THE NORTH-WESTERN PART OF THE KOLA PENINSULA

By A. A. POLKANOV, Member of the Academy

1. In 1933 N. A. Eliseev was sent at my suggestion to the Kola Peninsula to carry out supplementary investigations of the Gremiakha-Vyrmes pluton of alkaline rocks. Among many other instructions given to him, he had to search for new outcrops of nephelite rocks in the depression of Lake Kumojie, situated

15—20 km south-south-east of the Gremiakha pluton. This assumption of mine was based upon the findings of nephelite-syenite boulders of a non-Khibiny type: (a) in the depression of the Kola River, near the mouth of the Medvejia River (*11* on the map) and near the Loparskaya station (*10*): (b) in the depression of the Kitsa River, 18 km east of its mouth ((1), p. 454).

From what was known of the direction of the movement of glaciers it might be presumed that these boulders were brought from the south-west along the depressions of the Medvejia and Domashnyaya Rivers (?) (2), see map).

These data, along with the assumption that the dislocation of a north-north-west strike, with which the intrusion of the Gremiakha pluton was associa-

ted, could have been manifest also further south-south-eastward from this pluton in the direction towards the Khibiny subvolcano, made one search after the new intrusions of nephelite rocks in the first place in the depression of Lake Kumojie ([3], [4], [5]).

The quest was carried out by V. P. Popov, undergraduate of the Leningrad Mining Institute, who died in 1934 without having time to study materials collected. Examining his materials I succeeded in making out that Popov's search had been successful, and that he had discovered an intrusion of nephelite rocks on the eastern shore of Lake Kumojie.

2. The new data secured by Popov confirm in the first place that the region of the depression of Lake Kumojie is made up mainly of rocks of a composite complex of hypersthene gneissose-diorites, with inclusions of rocks of the type of amphibolites, as I have previously shown on the geological map ([1]). The new outcrops of oligoclase granites found may be the youngest differentiates of the same magma, or, like an injection of microcline granites, younger intrusions. It is very likely, too, that in this composite complex there are included in addition horizons of biotite-garnet-sillimanite gneisses.

3. The outcrop of nephelite rocks was discovered by Popov on the eastern shore of Lake Kumojie. In his diary we find the following entry: «...I have turned northward in order to search after the outcrops in the central part of the peninsula formed by a bent of the lake. On the pass from the southern slope to the northern I found outcrops of grey crystalline biotite rocks—specimens 84a and 84b». Specimen 84a proved to be pyroxene gneiss, while specimen 84b belonged to juvite. The exposure located further south (83) proved to be composed of hypersthene diorites. Therefore it is possible that the «peninsula» is composed chiefly of these rocks, and juvites are not widely developed.

The juvite was found to be a medium-grained rock with a trachitoid and banded structure, discernible under the microscope. The chief minerals are nephelite, diopside-aegirite and biotite; there are albite, albitized potash feldspar in a small quantity; the accessory minerals are apatite, calcite, and sphene.

Nephelite forms partly euhedral tables elongated perpendicular to the vertical axis, and includes lamellar albite in the middle part and needles of aegirite-augite in the peripheral part of the grains.

Pale-green diopside-aegirite forms aggregates of xenomorphic grains associated with xenomorphic greenish-brown biotite. These minerals form layers in the rock to which also sphene, apatite, and calcite are confined.

Among grains of nephelite there are arranged twinned grains of albite and grains of albitized potash feldspar. Juvite is very much like those of the Gremiakha-Vyrmes pluton ([5]).

4. Since the observations of Popov give no idea of the geology of the juvite intrusion, it would be difficult to say whether the discovery of this deposit goes to confirm the assumption advanced as to the tectonics of the depression of Lake Kumojie, or it is but a casual coincidence. Therefore, regardless of these conceptions, it will be useful for a future explorer of the region to cite also other data concerning the possibility of the development of rocks of the gabbro-syenite—nephelite-syenite stem of the type of the Gremiakha pluton in the depression (and on the adjacent mountains) stretching from this pluton to the south-east towards the Khibiny subvolcano.

5. On the mountains surrounding the depression, in addition to numerous diabase dykes, I found dykes of subalkaline and lamprophyre rocks. Here belong: (a) biotite-augite camptonites—four dykes on the Clita River (*14*) and a dyke on Mount Vuimvyd (*19*); (b) two dykes of olivine-plagioclase pyroxenite on mounts Olenja and Rypvyd (*15*, *16*); dykes of olivine-melagabbro on Mount Grudin (*20*) and two dykes of olivine-kaersutite gabbro on the Tuloma River (*13*). Possibly here belongs also the outcrop of pyroxene gneiss previously described by the present author (*21*), which resembles a gneissose gabbro enriched in ore ([1]).

The constant presence in all of these rocks of kaersutite, biotite and andesine makes them like the gabbro-syenite stem of the Gremiakha pluton. The exact

position of these rocks in the evolution of the whole series of alkaline rocks will be discussed elsewhere. All of these outcrops are confined to dislocation of almost meridional, north-western and in one case north-eastern strikes. But the thickness of these dykes does not exceed 10 m. Let us cite also the boulders and blocks of kaersutite cortlandite found by Popov (*18*), and the hortonolitic troctolite and gabbro of the same type as at the Gremiakha (*17*) in the depression of Lake Kumojie. Considering the course of the movement of glaciers, these boulders could not have been brought here from the Gremiakha pluton ([2]).

6. The nephelite rocks were encountered only in boulders.

The boulders found on the Kola River (*10*, *11*) belong to aegirite-nephelite-syenites which are unlike the corresponding rocks from the Gremiakha pluton. It should also be borne in mind that W. Ramsay has reported the occurrence of boulders of nephelite rocks of the non-Khibiny type within the space between the Kola and Pulozero Lake (*12*) ([7], p. 454).

Finally, on the Tuloma River, within the area from the Kola River to the Lukov Cape (*3—9*), I found 40 boulders of nephelite rocks (the greatest number at Krivetz, *8*). Among them there are distinguished groups of melanitic melteigites, ijolites, juvites, a similar group without melanite and, finally, a group of foyaite — nephelite porphyry — tinguaite. The first two groups of rocks are the most widespread ones. Together with these, three boulders of limestone skarns and a boulder of titaniferous magnetite were found ([1], p. 455, 495). The majority of rocks of these boulders are quite unlike those of the Gremiakha pluton, in which melanite was found in rare melanitic aegirinites and aegirite syenites only([3]). As the boulders of the rocks enumerated have not been encountered south of the mouth of the Koja River (*9*), it may be assumed that the plutons of these rocks are located somewhere in the depression of the Tuloma River, not farther south than the mouth of the Ulita River. The pluton of nephelite syenites found by Rabot in the Ristikenti region could hardly have served as a source of all these plutons ([6], p. 56; [1], p. 455).

7. All the data here reported and the finding of a new outcrop of juvite make it possible to assume that the region of the Gremiakha intrusion and the zone between this pluton and the Khibiny subvolcano may be the area of development of other intrusions of subalkaline and alkaline rocks of the type of the series of the Gremiakha pluton.

Leningrad State University.

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HISTOLOGY

THE CONNECTIVE TISSUE LAYERS OF DERMAL PART OF SKIN IN VERTEBRATES AND THEIR NOMENCLATURE

By A. A. BRAUN

(Communicated by A. A. Zavarzin, Member of the Academy, 24.I.1944)

An analysis of the abundant literary data available and of the author's personal observations enabled him to subdivide the connective tissue layer of the skin — the skin proper, corium or dermis — into definite layers in a manner equally applicable to all vertebrates. The dermis of the skin is naturally subdivided in all vertebrates into three layers, differing as to their structure and functional value.

1) The first layer, the external, subepidermal one, which is given by different authors the names of the *pars papillaris*, superficial, subepithelial, loose, spongy, vascular, *etc.* It mainly performs the trophic function with respect to the epidermis and the derivatives of the latter. In connexion with this function the subepidermal layer is characterized by an abundance of vessels and by a loose structure of the connective tissue. At the boundary with the skin epitelium the subepidermal layer is closely adherent to the surface of the epithelium and forms with it a rather thick basal membrane which serves as an anatomical and functional connexion between the connective tissue and the epidermis. On account of the main function performed by this layer, the most appropriate term for it seems to be that of the «trophic» layer. In animals with a strongly developed epidermis the trophic layer is rather thick and frequently forms papillae.

2) The second layer, the medium one, which is most commonly denoted as the reticular, or dense layer. The function performed by it in the skin is a «mechanical» one, and it is the essential layer of the dermal part of the skin. In accordance with the function it has to perform, the mechanical layer of the skin is built up of a compact connective tissue. In certain animals, however, the entire mechanical layer (in the Greenland shark, for example), or part of it (in the frog) consists, along with fibres, of a large quantity of gelatinous substance enclosed between compact fibrous membranes, which gives it the structure of a tissue of the turgescent type.

3) The third layer is the inner, deep lying, subcutaneous one. Like the outer layer, it plays but a subsidiary part with respect to the skin covering, which largely consists in bringing about a more or less mobile contact between the mechanical layer and the underlying tissues. It may therefore most appropriately be called the «desmal», or connective layer.

In number of vertebrates this layer performs a supplementary mechanical function in addition. It may accordingly contain rather voluminous accumulations of adipose tissue, which serve as elastic cushions enhancing the resistance of the skin to pressure.

By dividing the dermal part of the skin of various animals into the layers listed above, we become able to compare these layers within the limits of the whole group of vertebrates.

The trophic function of the subepidermal skin layer has more than once been pointed out in literature. Still more frequently stress has been laid upon the mechanical function performed by the compact layer. It consists of a dense connective tissue feltwork supporting the dermis. Individual writers have reported also the intimate connexion existing between the skin and the subcutaneous layer. And yet in the description of the histological structures of the skin made by modern authors the classification of the skin layers is not based upon their functional importance; as to the deep-lying, connective layer of the skin, it is usually considered as the subcutaneous fat tissue, subcutis, hypodermis.

The terminology applied for denoting the different skin layers was critically revised by Schaffer (7) who suggested a nomenclature of his own. In the connective tissue part of the skin this writer distinguishes two main layers: the derma and the hypodermis (*panniculus adiposus*); the former is subdivided by him into two layers: *stratum hypepidermale* (*papillare*) and *stratum texticulare* (corium), showing a texture of a tissue in the strict sense of this word. In this way Schaffer separates out of the connective tissue system of the skin its deep-laying layer. The present author cannot agree with this separation of the connective tissue part of the skin as being natural. As a matter of fact, it is not *stratum hypepidermale* (the trophic layer), but rather hypodermis (the desmal layer) which functionally approaches to *stratum texticulare*. Between the mechanical and the connective layer there is a certain structural similarity, as well. The separation of the connective tissue part of the skin into the derma, *i. e.* the *Lederhaut*, and the subcutaneous tissue may be of some use in leather manufacturing only, whereas biologically it is inconsistent. And the more so as the mechanical and the connective layer of the skin do in many cases quite imperceptibly merge one into each other, so that they can scarcely be delimited if at all.

There are still other reasons why the nomenclature suggested by Schaffer can hardly be admitted as a happy one. In the first line the term «hypodermis» has two different applications in histological literature: some of the authors (5,3), indeed, understand by this name the connective layer of the skin, while others (4) denote by it the cutaneous epithelium which underlies the chitinous layer in arthropods. By applying this term to the connective layer of the skin in vertebrates we do but aggravate the confusion that is actually prevalent in the terminology. Besides, we find it extremely inconvenient to use the terms derma and corium in different senses. In the course of the science's history the terms cutis, derma and corium were used in a most various sense by different authors; at the time being, in order to get rid of the imbroglio in terminology, it is necessary either to renounce to them altogether, or to adopt them as synonyms. The terms cutis, derma and corium may be used to denote the three layers of the connective tissue part of the skin as a whole. The skin as an organ, as a combination of epidermis and derma (corium and cutis) should keep the names of skin, cutaneous covering, *integumentum*, *integumentum commune*. It is in this sense that the terms cutis and derma were applied as far back as by Kölliker (2), whereas the term corium as a denotation of the connective tissue part of the skin as a whole was introduced by Schieferdecker(8).

The trophic layer of the skin, whose function is uniform throughout the cutaneous covering, displays no topographical variations of its histological structure. Unlike this, the structure of the mechanical layer is strongly affected by the different conditions of strain and pressure to which the cutaneous covering is subjected in the various regions. In all vertebrates, inclusive of mammals, the mechanical layer of the skin displays definite regularities of histological structure which correspond to the mechanical conditions prevailing in a definite area of the skin covering.

We have succeeded in revealing sharp distinctions between the structure of the mechanical layer of the skin at the dorsal and ventral surface of the body in terrestrial mammals. In the ventral region the mechanical skin layer is a rather loose structure; the collagenous bundles it is formed of are comparatively thin and they interweave mainly in a plane parallel to the skin surface. Unlike this «horizontal» type of structure, at the dorsal surface the mechanical layer consists of thick col-

lagenous bundles which are very tightly packed and densely interlaced. Here the meshes of the network mostly assume a vertical arrangement; their shape is much that of a rhombus, the sides of the latter being mostly situated diagonally with respect to the skin surface. Owing to an interlacement of the meshes and a presence of a large number of anastomoses between them, the mechanical skin layer at the dorsal side of the body is an especially dense structure. It should be added that it is much thicker there than at the ventral surface. From the median line of the abdomen towards the spinal column the «horizontal» type of the structure of the mechanical layer gradually changes to a «rhomboid-reticular» one; at the same time both the individual collagenous bundles and the mechanical layer as a whole become thicker.

The topographic peculiarities observed in the structure of the mechanical layer are in strict conformity with the functional conditions prevailing at a given anatomical region; viewed at this angle, the structures of the mechanical layer of the skin should be considered as functional structures. The «horizontal» habit of the network, the loose arrangement and poor thickness of the collagenous bundles are responsible for the elasticity of the skin layer over the abdomen, which is quite indispensable for an animal. On the contrary, the cutaneous covering must be as little extensile as possible at the dorsal surface of its body; its structure must be the more solid, the nearer the given area of the skin is situated to the spine. The ventral part of the skin covering is as it were «suspended» to the dorsal part; the strain experienced by the mechanical layer of the skin is therefore the stronger, the nearer a given area of the skin is situated to the spine column. The «rhomboid-reticular» texture of the skin over the dorsal surface and the greater thickness of the mechanical layer there prevents the skin from being stretched towards the ventral surface of the body. The larger the animal, the greater is the weight of its skin, consequently, the more important the strain experienced by the dorsal part of the covering; therefore the structure of the mechanical layer there is the most solid. This conclusion is in full agreement with the data obtained by Rumjantzew and his school(6), dealing with the histo-architectonics of the mechanical layer of the skin in swine and cattle; it is also in good accord with the descriptions of the structure of the skin covering of newborn hippopotamus, made by Schumacher(9).

The study of the skin covering in fish revealed a greatly uniform histological structure of the mechanical layer throughout the body. This should in the first line be put down to the uniformity of the extension of the skin covering as associated with the uniformity of the swimming movements made by the animal; secondly, it is also accounted for by that the dorsal part of the skin is not extended towards the ventral part of the body. Both at the ventral and dorsal surface of the trunk the mechanical layer is made up of horizontal collagenous bundles. The fibrillae in adjoining layers are arranged perpendicular to one another, intersecting the main axis of the body at an angle of about 45°. The fact that in horizontal strata the fibrillae are arranged diagonally with respect to the body axis permits the skin readily to extend, following the movements of the animal.

The structure of the mechanical layer in aquatic mammals, the dolphin and the seal, has been found to display certain features convergent with those in fish. Similar to the latter, they are characterized by an arrangement of the fibrous structures of the mechanical layer of the skin diagonal to the main body axis. Another typical feature in common is a rather monotonous structure of the mechanical layer throughout the body surface. Thus, similar functional conditions have led to the development in the course of evolution of similar tissue structure in animals belonging to remote taxonomic groups. An arrangement of the fibrous structures of the mechanical layer diagonal to the main body axis throughout its length is the most favourable for swimming movements. And being the most favourable, it has been fixed as a result of natural selection. The descriptions of the structure of the mechanical skin layer in a newborn manatee as available in literature make it possible to extend our conclusions to the third group of mammals as well.

Our investigations have shown that the prevailing interpretation of the connective framework of the skin in mammals as a compact amorphous connective tissue disagrees with what is actually known about it. As a matter of fact, the connective tissue framework of the skin, the mechanical layer of the latter, is a regular, orderly structure in all vertebrates. The mechanical layer of the skin is not merely a tissue serving as material. The regular arrangement of the collagenous bundles of the mechanical layer of the skin, the definite structure of the material they present, correspond with the function of this layer, that of a framework supporting the skin, which is a feature characterizing it as an «organ». Viewed at this angle, the mechanical layer of the skin should be considered as a tissue-organ similar to the tendons or fibrous membranes, and classed in the same tissue group with them. This group (dense connective tissues showing a regular structure) can be arranged, according to their complexity, into the following consecutive layer of structure: the tendons, as characterized by collagenous bundles oriented in the same direction; the fibrous membranes (fasciae and aponeuroses) built of collagenous bundles perpendicular to each other; the mechanical layer of the skin in lower vertebrates, built of collagenous bundles intersecting in three perpendicular directions; the mechanical skin layer in mammals, which represents a complicated three-dimensional network of collagenous bundles, in which the size and arrangement of the meshes is typical both of the given species and of the given body area.

The A. M. Gorky All-Union Institute
of Experimental Medicine.

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GENETICS

AUTOTETRAPLOIDY IN DIFFERENT VARIETIES OF BUCKWHEAT (*FAGOPYRUM ESCULENTUM*)

By V. V. SAKHAROV, S. L. FROLOVA and V. V. MANSUROVA

(Communicated by L. A. Orbeli, Member of the Academy, 29. III. 1944)

Our previous paper(2) dealt with the production of a first highly fertile tetraploid form from the buckwheat variety «Bolshevik». The present communication is devoted to the tetraploids experimentally produced from other varieties of buckwheat.

A beneficial peculiarity of the tetraploid buckwheat consists in its non-crossability with the original diploid forms(1). Owing to this, the 32-chromosome forms may be cultivated in the closest vicinity to 16-chromosome forms, without any danger of mutual cross-pollination. On the other hand, the 32-chromosome forms derived from different varieties intercross as freely as do the 16-chromosome plants of the same varieties. For this reason we had to sow the nine different varieties of buckwheat in different isolated localities.

It is a well-known fact that the yield of the buckwheat is influenced by the time of sowing, by the climatic conditions and by a number of edaphic factors. Since we were forced to cultivate buckwheat under different conditions no exact comparison of the yield of the different varieties could be made; the comparison of the varieties can be but a relative one.

Let us now proceed to the examination of the tetraploids belonging to different varieties, to their comparative test against the control, *i. e.* the diploid plants of the same varieties which were planted at the same time and under identical conditions in the immediate proximity of the autotetraploids.

Variety Kharkovskaya was represented by ten original tetraploid forms obtained through colchicine treatment in 1941. Six of them were propagated the next year; within the small first-generation progeny consisting of 21 plants there was noted a strong variation in fertility. The lowest number of seeds harvested from a single plant was 2; the greatest, 137. Only three plants were selected for further propagation, owing to both high fertility and good seed quality. Their progeny consisted of 193 plants (see general table summarizing data on the cultivation in 1943) which displayed a good performance, but were inferior to the control as regards fertility. With regard to fertility, the control variety Kharkovskaya gave such outstanding figures that they could be compared only with the best families of the polyploids of the «Bolshevik»; it is worth of remembering that in one of these (altogether 22 in number) the lowest mean number of seeds was 331 per plant, and in the other, the highest number was 779.

The high weight of the polyploid seeds and presence among autotetraploids of several plants which gave over 700 seeds give us right to consider the tetraploid Kharkovskaya buckwheat a rather promising form, although somewhat inferior to the tetraploid «Bolshevik».

Variety	Tetraploids (4 *n*)						Diploids (2 *n*)				Indices for 4 *n* in per cent to 2 *n*	
	Date of sowing	Progeny number	Number of plants	Mean number of seeds	Mean weight of seeds	Correlation coefficient	Number of plants	Mean number of seeds	Mean weight of seeds	Correlation coefficient	Mean number of seeds	Mean weight of seeds
Kharkovskaya	10.VI	X-1,2,3	193	269.2±13.2	31.4±0.3	+0.18±0.07	14	650.0±108.6	22.1±0.9	+0,03±0.27	41.4	142.1
Altay kaya	5.VI	A-1,2	110	218.2±14.2	35.0±0.4	+0.19±0.09	—	—	—	—	—	—
	2.VII	A-3	52	50.0± 5.0	26.0±0.6	+0.27±0.13	12	50.0±28 3	18.7±1.2	+0.59±0.19	100.0	139.0
Burjato-Mongolskaya	1.5V	M-1,2	186	93.0± 5.3	35.3±0.3	+0.13±0.07	28	167.9±34.4	25.5±0.8	+0.05±0.2	55.4	138.4
Kazanskaya	3.VI	K-1	24	70.8±15.6	29.1±0 1	+0.13±0.2	—	—	—	—	—	—
	3.VI	K-2,3	41	9.8± 1.7	23.8±6.1	+0.03±0.16	10	9.0± 3.0	19.4±1.8	+0.01±0.3	109.0	122 7
Spanish-silvery	19.VI	-1-1,2,3	182	23.4± 1.7	27.6±0.4	+0.32±0.07	15	39.3±11.7	16.1±1.3	+0.29±0.24	59.5	171.4
«Bogatyr»	28.IV	Sh-1	10	30.0±11.4	33.2±1 5	+0.29±0.29	7	17.9±13.0	24.5±1.6	+0.58±0.25	167.6	135.5
«BTSHA»	28.IV	T-1	21	22.5± 4.4	35.2±1.4	+0.4 ±0.18	13	9.6± 2.7	29.8±1.9	+0.26±0.26	234.4	118 1

Variety Altayskaya was represented by five original tetraploid forms. All of them were propagated and their first progeny, 9 plants in number, displayed the familiar heterogeneity with regard to fertility (from 4 seeds to 117 seeds per plant). Three best plants were selected for further propagation; they originated from three different polyploids and showed good performance with regard to fertility and seed characters in progenies A-1 and A-2. Considerably worse were the results with the progeny A-3 which is shown separately in the table.

We do not doubt that the difference indicated was due solely to surrounding conditions.

A late term of sowing of the progeny A-3, along with a lack of light and potting (which was done to save plants from early frost), all these factors caused oppression. The controls which were treated in exactly the same manner as progeny A-3, showed a similar reduction in fertility; the strong drop in the mean weight of seeds was about the same as in tetraploids. Unfortunately, there was no control to progenies A-1 and A-2, as only one single plant could be raised from 25 seeds sown; the remainder died on account of a strong crust formed after rainfall. By the way, the single control plant was killed by the first autumn morning frost. Neither this nor the two morning frosts which followed produced any effect on the tetraploid individuals of the Altayskaya buckwheat.

Variety Burjato-Mongolskaya was represented by two original autotetraploid forms only. In 1942 they produced from three plants 219, 188, and 66 seeds, respectively, *i. e.* high numbers, especially if it is considered that the plants were grown in pots. The next year the progeny of the two former plants was propagated; the fertility figures they showed were, at the first sight, unexpectedly low, both in absolute expression and if compared with the control. In the case in question a mistake was made in sowing. Buckwheat was sown very densely: 186 experimental plants and 28 plants of the control were given only 2.5 m^2 area. The robust, profusely ramiciferous Burjato-Mongolskaya buckwheat could not produce lateral branches owing to the crowded condition, so that a dense brush was formed of its central shoots. The control enjoyed better conditions owing to its slighter growth; this resulted in a fertility twice as great as in the case of the tetraploid. Further work should be done with tetraploids of the Burjato-Mongolskaya buckwheat; it is quite possible that it will show as good a performance, as the tetraploid of the variety «Bolshevik».

In the variety Kazanskaya we had five original autotetraploid forms, three of which were propagated. The progeny, 5 plants in number, showed a moderate fertility (from 16 to 78 seeds per plant). A rather low fertility was also obtained in 1943 when seeds of the three best plants were sown. It should be noted, however, that we were late with the harvest, which, probably, greatly reduced the yield; the latter turned to be extremely low in the control.

Attention is further called to the inferior indices of the seed weight. In the preceding generation they were considerably higher (from 32 to 38 g).

It is possible that inferior results shown by the whole material belonging to the variety Kazanskaya were due not only to hereditary properties of the polyploids, but to unsuitable edaphic conditions, too.

Out of the five polyploid forms of the variety Spanish-silvery four were propagated. Among the progenies consisting of 13 plants sharp variation in fertility was observed (from 10 to 182). In spite of the fact that only three best plants were selected for propagation, the next year the progeny showed very bad performance. The plants were robust, they developed well, but set seed poorly; 33 out of the total of 215 individuals produced no seeds at all.

The weight of the seeds was also lower than in the preceding generation (in 1942 the seed weight was from 30.0 to 46.0 g, while in 1943 the correspond-

ing figure was 27.0). One may see from the table that the control diploid plants of the same variety showed similarly very bad performance.

Varieties «Bogatyr» and «BTSHA» were represented by the original tetraploids each. The two varieties when propagated showed in the first generation a very low fertility. In 1943 the two have shown a like low fertility, despite the good development of the plants. The plants bloomed abundantly, but set almost no seed. In many individuals blooming continued during four months without any noticeable decline in its intensity. A very low fertility was shown also by the controls to the two varieties. The worst results were obtained with the autotetraploids of the variety Belorusskaya. Their fertility was so low that our efforts to propagate the three original forms obtained failed. The single plant of the second generation set no seeds in 1943.

We have come to the end of the survey of the polyploid forms which were produced by us in all the nine varieties of buckwheat studied by us. There was found a very wide variation with regard to fertility. Both the varieties tested and individual polyploids within the varieties differ sharply in this respect. By selecting plants yielding the greatest numbers of good and large seeds, we were able to fix these properties in the varieties Kharkovskaya, Altayskaya and Burjato-Mongolskaya. We hope that subsequent work with the best tetraploids of the above varieties will make it possible to introduce them into agricultural practice along with the tetraploids of the variety «Bolshevik». The desirability of the extension of the assortment of various polyploid forms follows from the necessity of introducing varieties which are adapted to the various conditions of the different regions of country.

Considerably inferior results have been obtained with the variety Kazanskaya. As to the varieties Spanish-silvery, «Bogatyr», «BTSHA» and Belorusskaya we must admit that the tetraploids obtained by us are hopeless as regards their fertility. In the course of our work with a great multitude of polyploid forms we became convinced that the most fertile forms usually are the most robust ones; however, not every robust form should be supposed to be fertile. The polyploids of the varieties «Bogatyr», «BTSHA» and Spanish-silvery may serve to show that plants of excellent strength which bloom abundantly do not set seed at all. The cause of this phenomenon will be analysed in a special cytological study. It is beyond doubt so far that tetraploid forms showing strongly reduced fertility should be traced back to progenitors which were hereditary inferior themselves, and that polyploidy could not possibly produce a beneficial effect in such a material. A poor fertility of the diploid control to these forms should only serve as a confirmation of the above said. It will be erroneous, however, to think that certain varieties are unable to produce valuable polyploid forms. We think that wide experiments on the production of new autotetraploids within these varieties may furnish new valuable forms. The work would be accelerated and would become especially efficient in the case tested, hereditary superior original material be selected.

Institute of Cytology, Histology and Embryology.
Academy of Sciences of the USSR.

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PHYTOPATHOLOGY

ON PHYTOTOXINS OCCURRING IN GRAIN RESPONSIBLE FOR «SEPTIC ANGINA»

By O. K. ELPIDINA

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The nature of toxic substances eliminated by fungi parasitic of plants has been investigated in the USSR by A. A. Richter and his pupils [1–5]. The phytotoxins, by which name these substances are known in literature, and a rather inappropriate name, by the way, the phytotoxins have been found to be simple structures.

To a smaller extent have been studied the phytotoxins which are responsible for the morbid phenomena in animals and man. Intoxication caused by them may occasionally affect large numbers and is not infrequently lethal. Much attention has been attached within recent years in the medical literature of this country to the «septic angina» [6–9], a disease which has been insufficiently investigated as yet.

Septic angina is known to attack certain animal species feeding on, and human subjects who use for their food such grain as had been left over winter in the field, or products prepared with such grain. Grain crops left unreaped throughout the period of thawing on humid plots open to the sun develop toxic properties. The same seems to hold for millet, buckwheat, and even for potato, according to information received from people, who suffered from the disease here described. The literature contains no comprehensive studies devoted to the chemistry of deteriorated grain, or to the causative agents of this deterioration. If we are to judge by some preliminary notes [12], no specific agents have been discovered at all. Rather trivial saprophytic and semi-parasitic fungi have been isolated from deteriorated grain, which are of frequent occurrence both in grain used as food and seed [13] used as sowing material.

It has been found that the toxic substances in question may be extracted from ground grain with the aid of water, but more readily with 70° alcohol or ether; they are heat resistant; when applied to the skin of a rabbit, they produce local oedema and hyperaemia; in the case of high concentration, necrosis.

The present author tested toxic extracts from deteriorated millet causing septic angina for the presence in them of phytotoxins. The test was carried out according to the method of wilting. The oily residue remaining after the extraction of millet in ether and upon total elimination of the latter was spread over the walls of a test-tube. The test-tube was then filled with water and left to stay for 24 hours during which the water-soluble substances were dissolved and washed out of the thin layer of the oily residue. After this leaves of chrysanthemum were immersed into the water infusion with their stalks and so kept at room temperature during 20 hours. As a result, the leaves kept in water extract made of the oily substance of toxic millet were found to have entirely lost their turgor, the edges of their leafe-blades became dry; unlike this, the leaves of the controls remained turgescent. The etherial oily extract obtained from millet flour by moistening it with alkali (in order more readily to extract the free bases) also resulted after 20 hours in a withering of the leaves and in a drying-up of the edges of their leaf-blades.

Simple nitrogenic substances of the type of urea have been reported considerably to affect the properties of complex nitrogenic substances, proteins ([16]) and antibodies ([17]) of an animal organism. As said above, the phytotoxins belong to simple nitrogenic substances. The general resistance of an organism affected by septic angina is considerably reduced. It appeared judicious to assume that the toxic principle of deteriorated grain, penetrating into the blood of an animal organism, is able to destroy in it the protective substances. In order to check up this assumption, andi-diphtheritic serum was taken, in which titre variation was studied after it had been directly acted upon with toxic extracts. Both serum and toxin were freshly obtained from the Metchnikoff Institute, Moscow, with titres determined there. The toxic principle was extracted from the millet grain with ether.

The variations in the titre of the serum were recorded by Ramon's flocculation method. Toxic extracts in the form of semi-liquid oil were added at an amount of 2 to 5 drops to every cm^3 of the serum, and the mixture was left to stay for 24 hours at room temperature. After this the titre of the serum was determined. Along with the investigation of the oil extracted from deteriorated millet grain, a control test was also run with oil extracted from normal millet grain.

The content of toxic extract in the form of an oily liquid attained 1 per cent to the weight of the millet grain under test. The results obtained are to be found below.

Experiment 1. Millet obtained from the Biochemical Institute of Academy of Sciences of the USSR, of low toxicity. 5 drops of an extract prepared from it were added to each cm^3 of the serum. Control titre of the serum 400 AU *, experimental titre 327 AU, a reduction by 18.25 per cent.

Experiment 2. Millet obtained from the Biochemical Institute of the Academy of Sciences of the USSR. Toxicity higher than in the former case. Each cm^3 of serum added 4, 3, or 2 drops of the toxin. The titre of the serum was determined after 24 hours. The results were as follows: 4 drops were found to reduce the titre of the serum to 327 AU, *i. e.* by 18.85 per cent; 3 drops, to 360 AU, *i. e.* by 10 per cent; 2 drops, to 400 AU, *i. e.* no reduction could be recorded.

Experiment 3. Millet obtained from the All-Union Institute of Experimental Medicine, from the Laboratory of Prof. Tovarnitzky. Its toxicity, as tested on rabbits, was conventionally estimated at 3 crosses. Each cm^3 of serum was added 5 drops of the usual extract, which resulted after 24 hours in a reduction by 35.75 per cent.

Experiment 4. The same millet as in experiment 3. Extraction with ether was carried out after alkalinization of the millet flour, until the latter showed a pronounced alkaline reaction. The titre of the serum showed a reduction by 38 per cent.

Experiment 5. Millet obtained from the Institute of Biochemistry of the Academy of Sciences of the USSR. Toxicity low. Extraction with water, at room temperature. Ratio of flour to water 1 : 1.5. The aqueous filtered boiled extract was added to the serum at a ratio 1 : 1. The titre of the serum was found to be reduced in the one case by 5.50 per cent, in another by 5.25 per cent.

From the figures cited above it may clearly be seen that the phytotoxins affect the antibodies contained in the serum, changing their ability to form flocculae with the toxin. It seems probable that penetrating with the food into the alimentary canal and subsequently in the blood of the animal, the phytotoxins cause alterations in the protective apparatus of the organism as a whole.

The present work has been carried out under the guidance of A. A. Richter, Member of the Academy, and Prof. K. T. Sukhorukov, to whom the author's heartiest thanks are due.

Laboratory of Phytosynthesis.
Academy of Sciences of the USSR.
Kazan Medical Institute.

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* AU denote antigenic units of Ramon.

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HELMINTHOLOGY

COMPARATIVE SUSCEPTIBILITY OF MOLLUSCS TO INVASION BY LARVAE OF NEMATODES, CAUSATIVE AGENTS OF PULMONARY HELMINTHOSES IN SHEEP AND GOAT

By E. A. DAVTJAN

(Communicated by K. I. Skrjabin, Member of the Academy. 30. III. 1944)

Pulmonary helminthoses in sheep and goat, the mülleriosis, cystocaulosis and synthetocaulosis, are of rather wide distribution in some regions of the Soviet Union (Transcaucasia, Kazakhstan), and the losses caused by them to sheep breading are considerable. As well-known, the causative agents of these helminthoses pass their developmental cycle with the aid of intermediate hosts, molluscs.

When studying the prophylaxis against the diseases mentioned above, it is very important accurately to determine the specific composition of the molluscs serving as intermediate hosts, to know the periods of development of their larvae. Of interest is also to evaluate and compare the part played by each separate species of molluscs in the spread of the helminthoses. None of those questions has been satisfactorily studied up to the present time.

In order to determine the specific composition of the molluscs which might serve as intermediate hosts for *Müllerius capillaris*, *Cystocaulus nigrescens* and *Synthetocaulus* spp. under the conditions of the Armenian SSR, 33 338 molluscs belonging to 38 species and 12 families have been tested for the degree of their infestation under natural conditions. 45 836 molluscs belonging to 51 species and 14 families have been tested for their susceptibility to the invasion by larvae of the above-listed species when infested artificially.

The results of the investigation are given below.

1. Contrary to the opinion which had prevailed until now, we found aquatic species of molluscs of the families *Limnaeidae* and *Planorbidae* to be susceptible to infestation with larvae of *Müllerius capillaris*. This discovery gives an essentially different trend to our understanding of the epizootics caused by this helminth and of the prophylaxis against it.

2. We have found, moreover, that the group of molluscs referring to the families *Clausiliidae*, *Cochlicopidae* and *Ellobiidae* are immune to the infestation with any of the species of pulmonary helminths of sheep and goat studied by us. These forms of molluscs dwell in rock crevasses or among pebbles, some of them inhabit marshy valleys.

3. In the case of both artificial and natural infestation of molluscs, we have found the larvae of *M. capillaris*, *C. nigrescens* and *Synthetocaulus* spp. to be endowed with the capacity of selectively invading definite species of molluscs. The different degree of susceptibility in the different mollusc species to definite nematodes may be estimated both by the different extension and intensity of the invasion, and by the periods necessary for the larvae to attain their invasion stage.

4. We have discovered a definite regular relation between the extension and the intensity of invasion and the developmental periods of the larvae: the more

extensive and intense the invasion, the shorter are the periods of development of the larvae, and inversely.

5. The species of molluscs which serve as intermediate hosts for the larvae studied by us, may be distributed in the following way, according to their ecological characteristics:

a) The larvae of *M. capillaris* are capable of invading 41 species of molluscs, comprising 2 aquatic species, 3 amphibiotic, 10 hygrophilous, 12 mesophilous and 14 xerophilous.

b) Larvae of *C. nigrescens* are able to infest 35 species of molluscs: 2 aquatic, 3 amphibiotic, 7 hygrophilous, 9 mesophilous and 14 xerophilous.

c) Larvae of *Synthetocaulus* spp. are capable to invade 20 mollusc species: 2 hygrophilous, 8 mesophilous and 10 xerophilous.

Thus, according to their degree of adaptation to the widest circle of intermediate hosts, the first place is occupied by *M. capillaris*, then follow larvae of *C. nigrescens*, while the last place is held by *Synthetocaulus* larvae.

6. In spite of the fact that the species of molluscs prone to be invaded by larvae of *Müllerius*, *Cystocaulus* and *Synthetocaulus* differ largely as to their ecological characteristics, they exhibit nevertheless a certain selectivity with respect to individual ecological groups of molluscs. Thus:

a) Larvae of *Müllerius* are found to prefer molluscs belonging to hygrophilous, aquatic and mesophilous ecological groups.

b) Larvae of *Cystocaulus* show preference for xerophylous, mesophilous and, partly, hygrophilous groups of molluscs.

c) As to larvae of *Synthetocaulus*, these choose as their intermediate hosts preferably molluscs of xerophilous or mesophilous characteristic, and much rarer such as belong to the hygrophilous group (2 species only).

On the basis of the different susceptibility of various mollusc species to larvae of *M. capillaris*, *C. nigrescens* or *Synthetocaulus* spp. we found it possible to class them among the following four main categories:

1. Obligatory intermediate hosts.
2. Facultative intermediate hosts.

We give these two terms the same meaning as suggested by Skrjabin and Schulz in 1937—1940. We find it expedient, moreover, to supplement them with two new categories of intermediate hosts, *viz.*:

3. Subobligatory intermediate hosts. This name is suggested by us for such intermediate hosts in whose bodies the larvae of pulmonary nematodes do not only attain their invasion stage, but in which the invasion reaches a high degree (above 35 per cent). Along with this, the periods necessary for the larvae of pulmonary nematodes to attain the invasion stage are rather protracted as compared to the obligatory intermediate hosts.

Larvae of *Müllerius capillaris*, in particular, which attain in obligatory hosts the invasion stage by the 14th—19th day, take no less than 45 to do so in the body of a subobligatory host.

4. Mortal. We suggest the name of mortal for the fourth class of intermediate hosts; in the bodies of these the larvae of pulmonary nematodes, though invaginating, fail to find suitable conditions for their development, and perish without having attained their invasion stage.

Veterinary Scientific Research
Institute of Armenia.
Erevan.

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